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ABSTRACT

A study of U.S. Air Force simulator training was conducted to identify factors that influence the effectiveness of such training and to learn how its effectiveness is being determined. The research consisted of a survey of ten representative Air Force simulator training programs and a review of the simulator training research literature. A number of suspected or potential factors influencing simulator training effectiveness were identified. These factors include simulator design for training, visual display fidelity, platform motion system fidelity, handling characteristics, training program features, trainee and instructor characteristics, and attitudes and expectations toward simulator training. The discussion of each factor reviews relevant literature and Air Force simulator design features and training practices. Ten simulator training effectiveness study design models were identified. Efforts by the Air Force to validate the simulator training activities surveyed are described in relation to these ten models. It was found that the programs surveyed had not been subjected to formal evaluation studies that would establish their training effectiveness in quantitative terms. Therefore, the influence of factors identified during the survey upon such training could only be hypothesized. Recommendations were made concerning research and administrative action that could enhance future simulator training effectiveness. (Author)

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Some Factors Influencing Air Force Simulator Training Effectiveness

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A study of U.S. Air Force simulator training was conducted to identify factors that influence the effectiveness of such training and to learn how its effectiveness is being determined. The research consisted of a survey of ten representative Air Force simulator training programs and a review of the simulator training research literature. A number of suspected or potential factors influencing simulator training effectiveness were identified. These factors include simulator design for training, visual display fidelity, platform motion system fidelity,

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FOREWORD

This report describes a research project that was undertaken to gain a better understanding of how simulator training might be made more effective in the U.S. Air Force. This effort was begun when the author was employed by the Human Resources Research Organization (HumRRO). The effort was completed and the present report prepared under the auspices of the Seville Research Corporation, under HumRRO subcontract number SubE 77-04-05. Dr. Caro is presently a Senior Scientist with Seville Research Corporation.

The project built upon an earlier literature review by the author when he was employed by HumRRO. That review was reported in "Some Factors Influencing Simulator Training Effectiveness," a paper presented at the Third Flight Simulation Symposium of the Royal Aeronautical Society, London, England, in April, 1976. The paper also was published as HumRRO Professional Paper 1-76, August, 1976.

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SUMMARY

PURPOSE AND APPROACH

A study of simulator training was conducted to identify factors that influence the effectiveness of such training and to learn how simulator training effectiveness is determined by operational users of simulators in the U. S. Air Force. The research consisted of two principal activities: a survey of representative Air Force simulator training programs, and a review of the simulator training research literature. Both activities concentrated upon the identification of factors influencing simulator training effectiveness and the methods used to determine simulator training effectiveness. During the survey portion of the research, simulator training activities of the Aerospace Defense Command, the Military Airlift Command, the Strategic Air Command, and the Tactical Air Command were visited, simulator training programs were observed, and interviews were conducted with simulator instructors and trainees as well as with personnel responsible for the development and management of simulator training. Ten combat crew training and continuation training activities at nine Air Force Bases were included in the survey. During the literature review, a variety of library sources were consulted, with a concentration on studies of training effectiveness and evaluation procedures.

FINDINGS

Ten simulator training effectiveness study designs that have been used in studies of simulator training effectiveness were identified and described in terms of simple models. The descriptions of these models include information concerning the relative value of each with respect to the relevance and objectivity of the data it yields. The efforts by the Air Force to validate the simulator training activities surveyed are described in relation to these ten study design models. It was found that the programs surveyed had not been subjected to formal evaluation studies that would establish their training effectiveness in quantitative terms. In those instances in which attempts had been made to validate simulator training, a tendency was noted to employ study models that were based upon subjective opinions rather than upon objective data collected during transfer of training studies.

A number of suspected or potential factors influencing simulator training effectiveness were identified during the project. These factors include simulator design for training, simulator visual display fidelity, simulator platform motion system fidelity, simulator handling characteristics, simulator training program features, simulator trainee and instructor characteristics, and attitudes and expectations toward simulator training. The discussion of each of these factors reviews relevant literature and Air Force simulator and training system design features and training practices.

The available information concerning the influence of these factors upon simulator training effectiveness was found to be quite limited. Because of the absence of objective studies validating Air Force simulator training effectiveness, the influence of factors identified during the survey upon such training could only be hypothesized. Additionally, definitive data could seldom be found in the literature reviewed that would permit the quantification of the influence of many suspected factors, and methodological problems made it difficult to generalize conclusions from the literature to the Air Force programs surveyed. Therefore, the information presented in this report regarding influences upon simulator training effectiveness in some instances is suggestive rather than conclusive.

RECOMMENDATIONS

Principal recommendations are as follows:

--Increased emphasis should be placed upon validating Air Force simulator training activities, employing validation study design models that emphasize objective measurement of trainee performance in operational aircraft against predetermined performance standards.

--Research should be undertaken to examine simulator design considerations as a function of specified training objectives and of the manner in which the devices are to be used to achieve those objectives.

--Research should be undertaken to determine the cognitive and visual cues essential to the attainment of visual training objectives and to find means of attaining those objectives that do not rely exclusively upon extra-cockpit visual simulation.

--Research should be undertaken to examine separately the influences of maneuver and disturbance motion cues, with particular attention to an analysis of disturbance motion cues in relation to specific training objectives.

--Reviews of Air Force simulator training activities should be conducted to identify areas in which better use could be made of available information in the areas of human learning and performance.

--Increased emphasis should be placed upon the needs of individual trainees in the development and administration of simulator training programs.

--Research should be undertaken to identify the instructor skills and techniques needed for effective and efficient simulator training, and training programs in which such skills and techniques could be developed should be provided all simulator instructors.

--Existing administrative practices related to simulator training should be examined to assure that they are conducive to favorable attitudes toward simulator training and to the effectiveness of that training.

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SOME FACTORS INFLUENCING AIR FORCE SIMULATOR TRAINING EFFECTIVENESS

I. INTRODUCTION

BACKGROUND

The U. S. Air Force presently is one of the major users of flight simulators, and the extent of its use of these devices is increasing. While the reasons for the growing role of simulators in aircrew training are manifold, the major factors to which these changes can be attributed include the increased capability of simulators resulting from recent engineering innovations; the combined effects of increased costs of operation of training aircraft and reduced Department of Defense funding levels; actual as well as potential future reductions in fuel resources needed to support aircraft operations; concerns of environmentalists over the possibly deleterious effects of aircraft operations upon the environment; and the increased safety in training which simulator training permits. The present trend toward more extensive use of flight simulators to meet operational training requirements is unlikely to be reversed because of the impact of factors such as those identified above, as well as the training benefits which have been attributed to the use of flight simulators in non-military settings.[1]

As simulator use continues to increase, the interest of the Air Force and other simulator users clearly is to achieve effective training through simulation rather than merely to use simulators more extensively. There has been a tendency in the past among some simulator training managers to make the tacit assumption that all simulators are optimally designed and used, so simulator training effectiveness is a matter primarily of how much the devices are used. Such is not the case, however. It is possible to use any simulator extensively, while at the same time to use it effectively. In one study,[1] for example, it was found that the extensive use of a particular device added cost, but no training value, to an already expensive pilot training program, a finding which was subsequently attributed largely to that particular device's less than optimum design.[2] Another study demonstrated that the training value of a device could be increased substantially without increasing the amount of device training time involved when needed changes were made in the manner in which it was used.[3] Effective simulator training is critical if the Air Force is to comply with the Department of Defense planning guidance goal of 25% reduction in the use of aircraft for flight training by 1981 while maintaining the present quality of that training.[4]

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[1] American Airlines, Inc. Flight Training Academy. Optimized Flight Crew Training, A Step Toward Safer Operations. American Airlines, Inc., Fort Worth, TX, 1969.

Because of its extensive present and future reliance upon simulators in meeting aircrew training requirements, the Air Force has a continuing interest in increasing the effectiveness of each of its simulator training programs. Two major thrusts characterize that interest: (a) the development of simulators with the potential capability for providing major portions of the training required; and (b) the development of techniques and procedures for simulator use, following systematic, analytic procedures such as Instructional Systems Development (ISD), which are directly responsive to training needs. Enhancement of the effectiveness of its simulator training is a major goal of the Air Force.

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[1] Isley, R. N., Caro, P. W., and Jolley, O. B. Evaluation of Synthetic Instrument Flight Training in the Officer-Warrant Officer Rotary Wing Aviator Course. Technical Report 68-14, Human Resources Research Organization, Alexandria, VA, 1968.

[2] Caro, P. W. Equipment-Device Task Commonality Analysis and Transfer of Training. Technical Report 70-7, Human Resources Research Organization, Alexandria, VA, 1970.

[3] Caro, P. W., Isley, R. N., and Jolley, O. B. Research on Synthetic Training: Device Evaluation and Training Program Development. Technical Report 73-20, Human Resources Research Organization, Alexandria, VA, 1973.

[4] Hearing Before the Subcommittee on Research and Development of the Committee on Armed Services. U. S. Senate, 94th Congress, Second Session, May 13, 1976. U. S. Government Printing Office, Washington, DC, 1976.

PURPOSE

The present study was undertaken in an attempt to gain a better understanding of how this training effectiveness goal might be achieved. Specifically, the primary purpose of the present study was to identify the principal factors that influence the effectiveness of Air Force simulator training programs. The need for such a study is based upon an assumption that some simulator designers and users may be unaware of factors that, if properly treated or managed, would markedly enhance the value and efficiency of simulator training. A likely consequence of lack of awareness of such factors is that simulator training effectiveness will suffer, e.g., skills that are critical to safe operation of an aircraft may not be developed, aircraft may be used unnecessarily for training, training costs may become excessive, or simulator training, although effective, may be conducted in an inefficient manner.

In order to identify factors that influence Air Force simulator training effectiveness, an immediate question arises as to the relevant criteria of effectiveness. Effectiveness implies that simulator training has some demonstrable effect upon performance of the trainees. Ideally, the effect should be positive in direction and should be evident either in terms of improved performance in an aircraft subsequent to simulator training, or in terms of more efficient or less costly attainment of a given level of skill.

The scope of the present research was limited to the collecting of already existing information concerning simulator training from Air Force and other available sources. Because of this limitation in scope, it was not possible during this study to verify experimentally that a particular factor did or did not influence Air Force simulator training effectiveness, except to the extent that existing experimental or other data could serve that purpose. Therefore, a secondary objective of the research reported here was to locate existing data that might verify the influence upon simulator training effectiveness of factors identified during the study. A part of this secondary objective was to determine the manner in which such existing data were obtained so that their validity and reliability could be assessed.

APPROACH

Conduct of the research described herein was directed toward two questions underlying its primary and secondary objectives: (1) What factors influence simulator training effectiveness? and (2) How was effectiveness of simulator training determined in those activities in which these factors were found to be operative? The research consisted of two principal activities, a review of the simulator training research literature, and a survey of representative Air Force simulator training activities. The literature review concentrated upon the identification of factors influencing simulator training effectiveness and the identification of methods suitable for determining simulator training effectiveness. Likewise, the survey of simulator training activities concentrated upon corresponding areas of interest: the identification of factors that were influencing the effectiveness of Air Force simulator training activities; and the effectiveness of the simulator training activities investigated during the study and the methods employed by the Air Force in determining their effectiveness. The literature reviews preceded the survey activities.

Based upon information developed during the literature review, interview outlines[1] were prepared for use during the survey of Air Force simulator training activities. The interviews were conducted on site at a number of Air Force bases where simulator training activities were under way. Interviews at these bases were conducted with a wide range of personnel involved in simulator training, including aircrew members who receive training in simulators, instructors who conduct that training, supervisors who manage both simulator and aircraft training, and other personnel such as ISD Team members who, by virtue of their assignment, are cognizant of simulator training activities and of the various factors that might influence the effectiveness of such activities at each of the bases included in the survey.

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[1] These outlines are contained in the Appendix.

Table 1 identified the Air Force Bases visited during this research and the simulators involved in the training activities investigated at each. These bases and simulators were selected to represent Air Force simulator training activities beyond the Undergraduate Pilot Training (UPT) level. UPT simulator training activities were not investigated during the present research because the nature of UPT simulator training is expected to undergo significant change in the near future with the introduction of new simulators currently being procured for that program.

TABLE 1. SIMULATOR TRAINING PROGRAMS SURVEYED

Air Force	Combat Crew Training		Continuation Training	
Commands	*Aircraft*	*Location*	*Aircraft*	*Location*
ADCOM	F-106	Tyndall AFB	F-106	Castle AFB
MAC	C-5	Altus AFB	C-5	Travis AFB
SAC	B-52	Carswell AFB	B-52	Castle AFB
	FB-111	Plattsburgh AFB		
TAC	F-4	Luke AFB	F-4	Eglin AFB
	A-7	Davis-Monthan AFB		

The simulator training programs included in the survey were selected to be representative of Air Force aircraft and mission types. Both Combat Crew Training (CCT) and Continuation Training (CT) simulator programs were surveyed for the Aerospace Defense Command (ADCOM), the Military Airlift Command (MAC), the Strategic Air Command (SAC), and the Tactical Air Command (TAC). For each command, the same simulators/aircraft were surveyed with respect to both CCT and CT, e.g., the MAC portion of the survey concentrated upon the C-5 aircraft for both CCT and CT activities. In the cases of SAC and TAC, the survey of CCT activities included an additional aircraft not included in the surveys of CT activities. This was done because of the large differences in aircraft configuration and crewing assignments, compared with the other aircraft surveyed, and the additional aircraft represented (i.e., the two-place FB-111 for SAC and the single-place A-7 for TAC). It was thought that including these additional aircraft might yield data of interest to the purposes of this project which would not apply to the other aircraft included in the survey. Thus, the survey examined six CCT and four CT programs of the four commands located at nine Air Force bases. Six different aircraft were simulated by the devices examined during the survey. For several of these aircraft, different models of the same aircraft were represented by these simulators, e.g., the B-52D and the B-52G.

In addition to the interviews conducted at the locations identified in Table 1, the simulators themselves were examined, and Air Force documents describing the devices and the manner of their use were reviewed. Particular attention was directed to seeking documented evidence of simulator training effectiveness at each location. Where no documented evidence of the effectiveness of simulator training could be found, personnel responsible for the conduct of such training were questioned extensively in an attempt to determine the perceived value, quantitative or otherwise, of such training and the bases for their perceptions. As was stated earlier, no attempts were made to conduct experimental studies to determine the effectiveness of simulator training activities.

ORGANIZATION OF THE REPORT

This report is divided into four principal sections, of which the present introductory section is the first. In Section II, methods of determining simulator training effectiveness are described, and the findings from the present research concerning representative Air Force practices in determining simulator training effectiveness are presented. Section III summarizes information obtained during the recent research concerning factors that influence Air Force simulator training programs and summarizes the results of the survey of the literature related to those factors. Conclusions and recommendations based upon the information developed during this research are to be found in Section 4.

II. METHODS USED TO DETERMINE SIMULATOR TRAINING EFFECTIVENESS

INTRODUCTION

The increased emphasis within the Air Force during the past few years upon the use of simulators in aircrew training has been noted in Section I. Because of the greater role simulators are now playing in Air Force preparedness, increased attention must be directed to assuring that simulators are appropriately designed and used,and to determining the extent to which they are effective in the achievement of designated training goals. The determination of simulator training effectiveness often has been neglected, however, because systematic, controlled studies involving these devices sometimes interfere with training schedules or because cognizant personnel may lack the time and resources necessary to conduct such studies. In addition, most personnel responsible for simulator use, understandably, are not trained as behavioral scientists,and are ill prepared with respect to knowledge of experimental design and performance measurement methodologies to validate their simulator training programs. Consequently, some simulator users are forced to assume that their simulator training programs are effective, an assumption that may or may not be correct.

During the conduct of the research described in this report, information concerning the effectiveness of the simulator training activities surveyed was sought. Simulator instructors, simulator training supervisors, and, where possible, ISD team members and senior Squadron and Wing personnel cognizant of simulator training activities over an extended time period were questioned concerning the known or established effectiveness of the simulator training being conducted at each location. Specific inquiries were made concerning the existence of documented evidence of any kind as to the effectiveness of entire simulator training programs and/or any element of those programs. Other questions concerned the manner in which the worth of simulator training had been determined and, in those cases in which an established simulator training program had been modified, what procedures were employed to provide assurance that such modification had a positive rather than a negative effect upon the program's training value.

In general, it was found that most Air Force simulator training programs had not been subjected to formal studies that would establish their training effectiveness in quantitative terms. The evidence of simulator training effectiveness that was found often had been gathered informally and suggested only a general value for simulator training. In no case was documented evidence found indicating a demonstrated benefit, where particular training objectives were concerned, of training in a simulator versus training in an aircraft (or other media). A comment made by one of the individuals interviewed illustrates the lack of emphasis at some bases upon determining simulator training effectiveness: "No one ever asked me before, 'How do you know the simulator training is effective?'" More often, however, informal evidence at least suggestive of the contribution of simulator training to overall CCT and CT program effectiveness was found. The manner in which that evidence was being obtained by Air Force personnel is discussed below.

TWO APPROACHES TO INVESTIGATING TRAINING EFFECTIVENESS

In examining the methods and procedures available for use in determining the effectiveness of simulator training, a distinction must be made between two approaches to such investigations: (1) studies to determine the effectiveness of a particular simulator training activity; and (2) research on factors influencing simulator training effectiveness. The first approach is concerned with validating a particular use of a particular device in meeting a particular training requirement. Personnel who undertake such single purpose studies typically have limited training in experimental design and data analysis techniques, and the designs they employ tend to be unsophisticated and involve no more than two groups of trainees, usually groups of opportunity. Since the chief concern in the conduct of these studies usually is practical significance or economic gain rather than statistical significance, formal statistical tests of significance often are not employed, and study results are judged simply by inspection of the data or by practical and economic considerations.

The second approach, research on factors influencing simulator training effectiveness, almost invariably is undertaken by personnel trained in research methods. These studies also may be relatively simple in design and analytic requirements. Since the purpose of such investigations is to gain information which will be used to design simulators and simulator training programs, however, more sophisticated experimental designs and data analysis techniques involving multiple values of one or more variables or factors under study are more likely to be used to increase experimental efficiency. Because of the complexity of such designs and the difficulty of interpreting both single factor results and their interactive effects, statistical tests usually are necessary. Sometimes, though, statistically significant differences in results between treatment groups that are important to understanding the factors involved may have little practical or economic significance.

Air Force personnel responsible for ongoing training programs are concerned primarily with the first of these approaches, that of determining the effectiveness of a particular simulator training activity. Personnel interested in the second, broader approach, research on factors which influence simulator training effectiveness, are more likely to be associated with research and development agencies such as the Air Force Human Resources Laboratories. The present survey of Air Force simulator training was directed primarily toward the activities of operational and management personnel, rather than toward trained research personnel with more general interests. The following section of this report describes techniques employed by the personnel surveyed to determine the effectiveness of the particular training program for which they are responsible. Also described are other techniques, or study design models, that could be considered by personnel responsible for future studies of the effectiveness of particular simulator training programs.

STUDY DESIGN MODELS

A number of study design models can be used to determine simulator training effectiveness, some of which are more suitable to the task than others. No single design is suitable for all simulator training effectiveness studies, however. While factors such as the availability of personnel and other resources, time limitations, competing training activities, and administrative constraints sometimes necessitate use of a less than optimum study design, the investigator must guard against using a design that cannot yield information suitable to his needs.

A number of study designs that have been used in attempts to determine the effectiveness of simulator training are listed below, along with comments concerning the circumstances surrounding their use and the general nature or relevance of the information they yield. The study designs are described in terms of simple models. Along with the description of each model is a summary of the uses made of it by the Air Force in determining the effectiveness of the simulator training program surveyed during the present research. In general, the models are presented in order of their overall merit for use in determining simulator training effectiveness.

The Transfer of Training Model

The Transfer of Training Model generally is the study design model most appropriate to determine whether simulator training has improved subsequent operational performance. The model is based upon the basic concept underlying the use of simulators, transfer of training. Transfer of training is a phenomenon that occurs when the existence of a previously learned behavior or skill has an influence upon the acquisition, performance, or relearning of a second behavior or skill. Thus, if a behavior is learned in an aircraft simulator, and the existence of that behavior or the fact of its having been learned has an influence upon the subsequent acquisition, performance, or relearning of behavior in an aircraft, transfer is said to have occurred. The influence of simulator training can be either positive or negative. In practice, the influence may be positive with respect to some behaviors and negative or neutral with respect to others. If the sum of these influences is positive, use of the simulator can reduce dependence upon operational aircraft during training by facilitating the learning of tasks that must be performed in those aircraft.

In its simplest form, the Transfer of Training Model involves two groups of trainees: an experimental group which receives simulator training prior to further training or performance testing in the aircraft; and a control group which receives all of its training in the aircraft. Alternatively, the experimental group could be participants in a newly developed simulator training program, and the control group could be participants in an existing simulator program. This design permits differences in performance in the aircraft between the experimental and control groups to be attributed to the influence of training received by the experimental group. The groups must be equated, of course, in terms of relevant prior training and experience.

In all research designs involving control groups, consideration must be given to whether the control "treatment" itself might influence that group's subsequent performance in the criterion situation. The influence could be facilitative, e.g., a period of rest for the control group while the experimental group engages in fatiguing or stressful training; or debilitating, e.g., a period of fatiguing or stressful activity such as operational missions or extended duty required only of the control group because of their availability for additional assignments. Particular care should be taken that members of neither group engage in flying or related operational activities likely to influence their performance on criterion tasks and thus invalidate experimental and control group comparisons.

During the present survey of the Air Force simulator training activities, no examples were found of the use of the Transfer of Training Model to determine the effectiveness of any of the ten simulator training programs surveyed.

The Self-Control Transfer Model

Variations of the basic transfer model described above have been discussed by Gagné, Foster, and Crowley;[1] Woodworth and Schlosberg;[2] Murdock;[3] and Campbell and Stanley.[4] One variation of particular interest is useful in a situation in which a device might be used at an intermediate stage of training, i.e., when operational training is interrupted for a period of training in a simulator. In such a situation, the students in the experimental group could serve as their own controls, and performance data obtained in the operational aircraft immediately following simulator training could be compared with similar data obtained in the aircraft immediately prior to engaging in simulator training. The difference in these two sets of performance data, then, could be attributed to the intervening simulator training program. The results of such a study might be suspect, however, because of the confounding effects of forgetting (or reminiscence), particularly if there was a significant time interval between initial and subsequent practice in the operational vehicle.

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[1] Gagné, R. M., Foster, Harriet, and Crowley, Miriam E. The Measurement of Transfer of Training. Psychological Bulletin, 1948, 45, 97-130.

[2] Woodworth, R. S. and Schlosberg, H. Experimental Psychology. New York: Henry Holt and Company, 1960.

[3] Murdock, B. B., Jr. Transfer Designs and Formulas, Psychological Bulletin, 1957, 54, 313-326.

[4] Campbell, D. T. and Stanley, J. C. Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally, 1963.

Although a number of opportunities exist to employ the Self-Control Transfer Model to determine whether various Air Force simulator training programs are effective, no instances were found during the present survey of Air Force training in which this model has been employed in any formal sense. Two examples of informal use of the model by Air Force personnel are described below. However, the nature of the data employed in each case, i.e., the absence of negative feedback in one case and unsubstantiated opinion in the other, made questionable in these instances the value of the model and the interpretations of the results.

Flight performance of aircrews coming from other bases to participate in one simulator continuation training program is evaluated in flight by examiners at their home station from time to time. Presumably, some of these evaluations take place before and some after participating in continuation training and could provide evidence of the effectiveness of such training. There is no system for feedback of information from the home station concerning the performance of the returning aircrews that could be attributed to the training they received. However, the absence of negative feedback has been cited as evidence that such training is effective.

The simulator used for continuation training at another base became available only recently, so it now constitutes an additional capability that might be used to enhance the operational readiness of the assigned pilots. No formal attempt has been made to determine whether the pilots now receiving the additional training are more proficient than they were before the device became available, however. A senior instructor pilot expressed the strong opinion that there had been specific improvements in squadron pilots' in-flight capabilities following introduction of simulator training, particularly with respect to intercept missions, but no data had been assembled to verify this opinion.

The Pre-Existing Control Transfer Model

There are instances in which a concurrently trained control group may not be necessary. For example, when simulator training is added to an existing training program, or when a new simulator training program replaces an old one, student performance data from the existing or older program can be compared with comparable data from the new program to determine the latter's effectiveness. For such a comparison to be valid, the pre-existing data must have been gathered under conditions which would have been applicable to a control group trained concurrently with the experimental group. A disadvantage of the Pre-Existing Control Transfer Model is that differences in performance between the two groups may be the result of chances which have occurred in the population during the time between which the experimental and control students were drawn.

Historic records at a number of the bases involved in the present survey indicate that the hours programmed for flight training were reduced following introduction of an additional simulator capability (e.g., a visual display attachment) or following an ISD activity related to increased use of simulation. While it is not possible to attribute those reductions in scheduled flying time solely to increased effectiveness of the simulator training, it is at least likely that such reductions would not have been acceptable to the command involved had not the reduction presumably been offset by increased simulator training effectiveness. Unfortunately, hard data generally do not exist that can be used to demonstrate that these reductions were justified by a more effective simulator training. Therefore, it is possible that at least a portion of the reduction in flying hours which accompanied changes in some simulator training programs may have been based upon administrative action rather than upon actual simulator training benefits.

When training in a cockpit procedures trainer was added to one of the

Combat Crew Training programs surveyed, the amount of time devoted to procedural training in the simulator was reduced. The basis for the reduction was the informal observation that the simulator was no longer required for the development of certain skills associated with the location and activation of selected cockpit controls. This reduction in the need for the simulator to be used for selected training previously conducted in it permitted additional tasks to be included in the simulator training program within the same scheduled time, thus increasing the scope of simulator training in that particular program.

Personnel at another base reported instances in which CCT students had not participated in the normally prescribed simulator training before their first flight in the aircraft (reasons not given). The reported result was that the first aircraft flight was considered only a familiarization flight during which the training usually conducted on such flights could not be accomplished. Although no formal attempt was made to assess the relative skill of these students vis-a-vis students who received the prescribed simulator training, the instructors involved noted a significant difference in their knowledge and ability in the air. Whether their failure to receive the prescribed early simulator training led to a detectable difference in performance at the end of the training program for the few students involved is not known, nor is it known whether the loss of initial simulator training had to be compensated by additional training time in the aircraft.

The Uncontrolled Transfer Model

There are circumstances in which a separate control group cannot be employed, the Self-Control or the Pre-Existing Control Transfer Models are inappropriate, and suitable control data do not exist. Such circumstances might be dictated by political, administrative or safety considerations. For example, it might be unacceptable to "penalize" members of one group by requiring that they undergo a different and possibly inferior training program. In some instances, a control group simply may not be feasible, e.g., the effectiveness of lunar landing simulators could not be determined by employing a no-simulator training control group of astronauts.

When a control group cannot be employed and suitable control data do not exist, simulator training effectiveness can be established by determining whether students can perform a particular task in the operational vehicle, following its learning in the simulator, without an opportunity to learn that task in the operational vehicle. Data gathered under this model will be suspect, since it cannot be shown conclusively that the behaviors involved can be attributed solely to simulator training. Nevertheless, such data can carry considerable weight, particularly when a task critical to flight safety is involved and a plausible case can be made that the underlying skills probably are attributable, at least in part, to the simulator training program.

Many instances were found among the Air Force programs surveyed in which the Uncontrolled Transfer Model has been applied to determine the effectiveness of a particular simulator training program. These instances are typified by simulator training followed by further training in the aircraft, during which trainee performance is assessed in some fashion. Although almost all Air Force CCT and CT programs follow some variation of this sequence, the idea of using the resulting aircraft performance assessment data to validate simulator training effectiveness is not pursued. In fact, the in-flight performance assessment is more likely to reflect a number of factors other than simulator training effectiveness because of the structure of the overall training program and the point during flight training at which the assessments are made.

An example of the informal use by the Air Force of the Uncontrolled Transfer Model noted during the present survey involved the A-7D aircraft in the CCT program at Davis-Monthan Air Force Base. This program can be considered to be an application of the present Model in that the first flight in the aircraft can be viewed as an informal examination flight in which specific skills, those associated with taking off and landing the aircraft, can be assessed.

The A-7D is a single place aircraft, and all training flights in it must be solo. The fact that the first flight in this aircraft in the CCT program is almost invariably successful to one degree or another suggests that the training the students receive prior to that flight is effective. The student pilot learns to take off and land the aircraft in the simulator using the Heads Up Display (there is no extra-cockpit visual display on the device). On his first flight in the aircraft, he apparently relies upon this training (and his previous UPT experience in the T-38) in order to take off and land the A-7D aircraft without a qualified pilot on board. The extent to which the simulator training contributes to his ability to perform safely during this first flight cannot be determined more precisely using the Uncontrolled Transfer Model, however.

A number of other assumptions of the value of simulator training were cited during the survey which could be considered to be based upon application of the Uncontrolled Transfer Model. Each involved a particular task for which training was conducted in the simulator and for which benefits of that training were presumably noted in the aircraft during subsequent training flights. For example, performing an engine start for the first time in a simulator is a time consuming activity. However, pilots who have mastered that task in the simulator typically perform their initial engine start in the aircraft fairly rapidly.

The Simulator-to-Simulator Transfer Model

Many studies of the influence of specific features of simulators or simulator training programs upon their training effectiveness involve transfer of training from one simulator to another rather than to operational equipment. For example, a study of the role of platform motion upon pilot training effectiveness might involve training in a simulator without motion, followed by performance evaluation in the same or another simulator with motion. This design, which might be employed when no aircraft is available, is based upon an assumption of equivalence, so far as criterion performance is concerned, between the second simulator and the unavailable aircraft. This is a tenuous assumption, and it is conceivable that conclusions based upon transfer of training data derived through use of this model could be erroneous. In any event, no instances were found during the present survey in which the Simulator-to-Simulator Transfer Model had been employed to determine the effectiveness of an Air Force simulator training program.

There is one situation in which the Simulator-to-Simulator Transfer Model is appropriate. That situation exists when the second simulator

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is the criterion vehicle. For example, the effectiveness of training in a part-task training device can be determined by measurement of performance in a full-mission simulator if the objective of such part-task training is to reduce the use of the more complex device. In this situation, it would be presumed that performance in the simulator would involve intermediate training objectives, with the final objectives relating to subsequent performance in an operational vehicle. The situation described here is an application of one of the Transfer Models described earlier, with the second simulator equating to the operational vehicle itself.

The Backward Transfer Model

Another simulator evaluation design, known as backward or inverse transfer of training, is based upon the transfer of training concept and has been described by Adams and McAbee.[1] In a backward transfer study, an operator who already has demonstrated mastery of relevant training objectives in the operational vehicle is "transferred" to the simulator, where he is required to perform tasks corresponding to those he has mastered operationally. If he can perform such tasks to criterion levels without practice in the simulator, backward transfer is said to have occurred, and this fact is taken as evidence that transfer in the simulator-to-vehicle sequence, although of unknown quantity, will be positive.

The backward transfer design should be used with caution for at least three reasons: (1) positive results assume (possibly incorrectly) that a suitable training program exists for the simulator; (2) experienced personnel already proficient at operational tasks may have highly generalized skills not possessed by recent training program graduates and may be able to transfer to the device because of such general skills rather than skills needed to operate a particular vehicle or perform a particular mission; and (3) the simulator may be suitable designed for the evocation of a particular set of behaviors by skills performers, but may lack the cues essential to the development of those behaviors.

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[1] Adams, J. A. and McAbee, W. H. A Program for a Functional Evaluation of the GAM-83 Melpar Trainer. Report No. APGC-TN-61-41, USAF Air Proving Grounds, Eglin AFB, FL, October 1961.

While backward transfer data should not be the sole justification for adopting a particular simulator, one would be hesitant to recommend a program involving a device which could not be handled by competent pilots. Negative results could be misleading also, however. It is possible for some tasks to be performed in the aircraft by personnel who use cues not present in the simulator, and therefore, they could be unable to perform such tasks in the simulator without training in it, while the same simulator may provide other cues which trainees can learn to use to perform those same tasks in the simulator for subsequent transfer to the aircraft.

No evidence was found of the application of this model in order to assess simulator training effectiveness in the Air Force programs surveyed. In several simulator training programs, there were anecdotal reports of pilots having difficulty flying the simulator after learning to fly the aircraft, but there was no evidence that such information had led to an investigation to determine whether negative transfer might be a significant problem in these programs.

The Simulator Performance Improvement Model

A presumably essential feature of an effective simulator training program is improvement in the performance of trainees in the simulator as a result of training they receive in the simulator. If such improvement does not occur, there would be little expectation that subsequent operational performance would be improved as a result of simulator training. Because of this dependency relationship, improvement in performance in the simulator often is cited as evidence that simulator training is effective. This typically is done when circumstances preclude the employment of a transfer model to determine simulator training effectiveness. Examples of the application of the Simulator Performance Improvement Model are relatively common, e.g., the evaluation of spacecraft simulator training programs before launching manned spacecraft, and simulator motion system training effectiveness studies conducted in the absence of an in-flight performance evaluation condition.

Clearly, there are circumstances in which the Simulator Performance Improvement Model can provide the best available estimate of whether a simulator training program is effective. It must be noted, however, that this model yields only indirect evidence of simulator effectiveness. It can show that a necessary condition has been met, but it does not justify the conclusion that the improved performance in the simulator will result in improved operational performance. This model, thus, is most useful in a negative way: if no improvement occurs in the simulator, none should be expected operationally.

The effectiveness of all Air Force simulator training programs included in the present survey was judged, at least implicitly, according to the Simulator Performance Improvement Model, and in some cases, such judgments were the chief basis for determining a program's effectiveness. At one base, for example, trainees were reported to be more proficient in the simulator on the final day of Continuation Training than on the first, although no data have been gathered to support this report. The effectiveness of the training each student receives is considered to be evidenced by the increased simulator proficiency he exhibits at the end of the five-day CT program. At another base where Combat Crew Training is conducted, the chief basis for judging simulator effectiveness is the changes which are reportedly observed to occur in trainee performance during such training, i.e., pilot trainees become proficient at flying the simulator.

At other bases, more formal attempts are made to verify that trainee performance improves during the course of simulator training. For example, in one of the CCT programs surveyed, personnel from the ISD team sometimes fly with a student in the simulator to "verify" that he has met the training objectives specified for the preceding simulator training flights. Personnel from the Stan/Eval Group also give checkrides in the simulator at fixed points during training, and proceeding to subsequent training activities is dependent upon passing such checkrides. Since the students involved have been engaged in a variety of training activities, including training in the aircraft in some cases, performance during such a checkride in the simulator cannot always be attributed solely to earlier training received in the simulator, however.

The Simulator Performance Improvement Model was cited by personnel who developed one of the CCT programs included in the survey as the basis for determining how much simulator training to include in the overall training program. They reported that their simulator training was validated through an examination of trainee grade slips in the simulator. When grade slips indicated that performance in the simulator no longer could be improved with more simulator training, the amount of training in the simulator the program then contained was considered appropriate, and the use being made of the simulator was judged to be effective on that basis.

The Simulator Fidelity Model

When data describing trainee performance are not readily available, other kinds of data thought to reflect simulator training effectiveness may be sought. Several models have been employed under such circumstances to generate data related to the simulator itself or to the manner of its use. One of these, the Simulator Fidelity Model, yields data which describe the simulator in terms of its fidelity, i.e., the physical correspondence between it and the operational vehicle, equipment or facility. Use of this model is based upon the assumption that a high fidelity simulator will yield high transfer; a low fidelity simulator will yield less--or even negative--transfer.

The Simulator Fidelity Model often has been used as an expedient when data reflecting trainee performance could have been obtained, although the model also has been used when no other kinds of data were available. The model has wide appeal among operational personnel who are not familiar with the complexities of transfer of training, and who lack training in experimental methodology and performance measurement. It can be employed by anyone familiar with the operational vehicle, does not require test subjects and other resources, and is based upon popularly accepted theoretical constructs underlying transfer of training, e.g., Osgood's[1] transfer surface illustrating the assumed relationship between stimulus similarity, response similarity, and transfer. Systematic, analytic procedures have been developed for the employment of this model that take into account fidelity of both the stimuli the simulator presents to the trainee and the responses he makes to those stimuli.[1] While such procedures increase the objectivity of the simulator fidelity data yielded by the model, they do not overcome the basic deficiency of the model itself: it yields a measure that may be unrelated to operational trainee performance.

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[1] Osgood, C. E. Method and Theory in Experimental Psychology. New York: Oxford University Press, 1953.

Data describing simulator fidelity might be used as a partial basis for predicting simulator training effectiveness, but its use for determining simulator training effectiveness is inappropriate. Bryan and Regan[2] have noted that a simulator can be a very faithful copy of operational equipment and be either effective or ineffective with respect to a particular training requirement. In fact, well designed training equipment may deviate intentionally from fidelity in order to promote learning. In an even stronger criticism, Adams[3] stated that equating training effectiveness with fidelity is a cover-up for our ignorance about transfer and leads to the development of possibly unnecessarily costly devices. In any event, the Simulator Fidelity Model ignores the manner in which a device is used and the objectives of device training. These two considerations underlie any determination of simulator training effectiveness.

In spite of the significant shortcomings of the Simulator Fidelity Model as a design for determining simulator training effectiveness, it was widely used for that purpose at the Air Force bases visited during the present survey. A tendency was noted during the survey for many Air Force personnel to equate physical correspondence between the device and the aircraft with training effectiveness and to judge effectiveness purely on the basis of that correspondence. The judged fidelity of several of the simulators, particularly those that included motion simulation, was cited as evidence of the effectiveness of the simulator training available using those devices. Further, the more complete simulation expected to be obtained through future modification of some of the devices, e.g., the addition of radar land mass simulation to the FB-111 simulator, was cited as evidence that future simulator training would be even more effective.

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[1] Caro, P. W. Equipment-Device Task Commonality Analysis and Transfer of Training. Technical Report 70-7, Human Resources Research Organization, Alexandria, VA, June 1970.

[2] Bryan, G. L. and Regan, J. J. Training System Design. In Van Cott, H. P. and Kinkade, R. G. (Ed.), Human Engineering Guide to Equipment Design (Rev. ed.). Washington: Government Printing Office, 1972.

[3] Adams, J. A. Research and the Future of Engineering Psychology. American Psychologist. 1972, 27, 615-622.

The emphasis upon simulator fidelity as a basis for judging simulator training effectiveness is illustrated by the requirement of some Air Force regulations that simulator training programs be validated by determining whether the simulators used in those programs are being maintained in a manner that permits faithful simulation of the aircraft involved. For example, SACR 50-46 specified that, quarterly, standardization personnel must evaluate each SAC simulator to identify operational serviceability problems. The assumption is made that a simulator that passes this evaluation, and which is used in accordance with specified procedures, is effective. It is understood that emphasis during these evaluations is upon verifying that the simulator operates within its design limitations with respect to fidelity of simulation.

The Simulator Training Program Analysis Model

Another model, sometimes employed when trainee performance data are not readily obtainable, is the Simulator Training Program Analysis Model. Use of this model involves analysis of the way the simulator is used to determine whether the training program is well designed, is directed toward the attainment of appropriate training objectives, and/or employs modern or innovative training techniques. While use of this model can pinpoint possible factors limiting the effectiveness of simulator training in a particular instance, it will not indicate whether such training is effective. Use of this model in conjunction with the previously discussed Simulator Fidelity Model can be particularly helpful in optimizing simulator training effectiveness, but determining the extent of that effectiveness must be accomplished through use of other models.

Jeantheau[1] suggests using these two analytic models in combination to obtain a "qualitative" assessment of simulator training effectiveness. Such an assessment does not involve measurement of any kind and is based upon judgments made against a priori criteria related to training equipment and processes rather than to trainee performance. Their use in combination probably would not yield a more valid assessment of simulator training effectiveness than would either used alone.

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[1] Jeantheau, G. G. Handbook for Training Systems Evaluation. Technical Report NAVTRADEVCEN 66-C-0113-2, Naval Training Device Center, Orlando, FL, January 1971.

The previously cited SAC Regulation 50-46 specified that the quarterly examination of SAC simulators by standardization personnel will include examination of the simulator training program "to assure that only current procedures are included in the curriculum." These quarterly examinations are intended to verify that simulator training is effective, although the regulation does not contain a requirement for the standardization personnel conducting the examination to inspect trainee grade slips or other evidence of changed trainee performance in the simulator or in the aircraft.

Other evidence of the use of this model to establish the effectiveness of Air Force simulator training also was cited by several of the personnel interviewed. At one base, changes in the simulator syllabus to include more training objectives was cited as evidence that simulator training effectiveness had been increased. (In that program, increased effectiveness had been equated with increased scope of the training offered.) At another base, analyses of simulator training programs by ISD and other specially trained personnel were conducted to verify that simulator training was effective, i.e., that the content of the training program corresponded with the recommendations of the ISD team.

The Opinion Survey Model

There are circumstances under which one might wish to determine the effectiveness of simulator training when operational training or performance testing is not feasible, data on performance in the simulator are not available, and the simulator and its training program cannot be analyzed. For example, it is sometimes necessary to make decisions concerning the training effectiveness of a newly developed simulator (or a simulator under development) before a study based upon another design model can be conducted.

Some analyses have attempted to evaluate simulators by asking operators, instructors, training specialists, and even students, their opinions concerning simulator effectiveness, i.e., the perceived training value of the device or certain of its features, or the probable impact upon subsequent operational performance of training in the simulator. Such opinion data often have little merit and even when of value may easily lead to erroneous conclusions. The writer has observed instances in non-Air Force training programs in which evaluations based upon operators' and instructors' opinions yielded effectiveness estimates unrelated to data subsequently obtained in transfer studies involving the simulators in question. Furthermore, the evaluations were often expressed without regard to the manner of use or the objectives of simulator training. Meister, Sullivan, Thompson, and Finley[1] found that estimates of simulator training effectiveness based upon instructors' opinions varied as a function of the different instructors expressing the opinions. The unreliability, and even invalidity, of determinations of simulator training effectiveness based upon opinions of instructors and other experts probably are due in part to attitude factors such as those discussed by Mackie, Kelley, Moe, and Mecherikoff,[2] as well as to the inherent unreliability of such judgments. In the final analysis, simulator training effectiveness must be established by trainee performance, not instructor, operator, or trainee opinions about the device and its probable usefulness.

The Opinion Survey Model clearly was a commonly used method for determining the effectiveness of many of the Air Force simulator training programs surveyed. Opinions that existing simulator training programs were effective were so strong at several of the bases surveyed that no need for further validation of those programs was acknowledged. At one of these bases, an ISD effort was underway which presumably would result in changes in the existing simulator training, but no plans to validate future simulator training were included in the ISD program except [illegible] have the program inspected by the ISD team itself to verify that it was being conducted as the team directed, and to ask trainees for their opinions regarding its value to them.

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[1] Meister, D., Sullivan, D. J., Thompson, E. A. and Finley, D. L. Training Effectiveness Evaluation of Naval Training Devices. Part II: A Study of Device 2F55A (S-2E Trainer) Effectiveness. Technical Report NAVTRADEVCEN 66-C-0113-2, Orlando, FL, January 1971.

[2] Mackie, R. R., Kelley, G. R., Moe, G. L. and Mecherikoff, M. Factors Leading to the Acceptance or Rejection of Training Devices. Technical Report NAVTRAEQUIPCEN 70-C-0276-1, Naval Training Equipment Center, Orlando, FL, August 1972.

The validation of the effectiveness of one CCT program surveyed rests primarily upon feedback from students obtained from end-of-training critiques. All suggestions contained in such critiques for improving the program are considered, and if there are several suggestions along the same line, change in the simulator training program becomes probable. Once such changes have been made, validation of the effectiveness of the resultant simulator training would be provided by subsequent reviews of student critiques. Presumably, a program that receives few suggestions for change would be judged to be effective, and further improvements would not be sought. Such a procedure is questionable.

Validation of the effectiveness of several other simulator training programs surveyed was reportedly based upon syllabus review by instructors and critiques by trainees. Suggested changes by instructors almost always lead to changes in such programs, so there are frequent changes that are not subjected to external validation. All changes in the simulator training that are intended to increase effectiveness are validated by obtaining a consensus of the instructors who administer it to students.

Many of the applications of the Opinion Survey Model noted during the present survey were quite informal. By contrast, a more formal evaluation of the limited visual system (LVS) for the C-5 and C-141 flight simulators at Altus AFB has been conducted.[1] Opinions concerning the worth of the LVS vis-a-vis CCT trainee performance and training efficiency were gathered via carefully prepared questionnaires that were completed by simulator instructors, students, staff agencies, and units to which graduates were assigned. Based upon the responses made to the questionnaires, conclusions were drawn concerning the effectiveness of the LVS and the associated training programs, including possible reduction in training flying hours through use of the LVS. While the planning effort that went into this study and the use of a comprehensive questionnaire probably contributed to the completeness and reliability of the opinion data thus obtained, the basic deficiency of the Opinion Survey Model as a means of assessing simulator training effectiveness must be considered in assessing this study's conclusions.

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[1] C-5/C-141 Limited Visual System. Operational Test and Evaluation Final Report 5-10-73. Headquarters, Military Airlift Command, Scott AFB, IL, November 1974.

COMMENT

In spite of the general absence of formal evidence of the value of the Air Force simulator training activities surveyed, a strong belief was noted during the survey that simulator training is a valuable training tool. Instructors and other personnel responsible for simulator training frequently expressed the belief that their simulator training programs contribute significantly to the cost effective conduct of aircrew training in both the CCT and CT programs they administered. Likewise, trainees typically expressed a dependency upon simulators so far as their progress through the various training programs was concerned. Simulator training clearly is an accepted part of present day Air Force aircrew training, and the personnel involved in that training are firmly convinced of its effectiveness.

It may be that simulator training has become too well accepted by the Air Force. The skepticism that characterizes some other training programs--a skepticism that was not widely noted during the present study--serves a useful purpose. It leads to the requirement that any simulator training activity be justified in terms of its training value and cost. As a consequence, some simulator training programs have been rejected when their value could not be established, and others have been refined on the basis of information made available during evaluation studies.

It is not intended here to suggest that any Air Force simulator training activities are ineffective and should be discarded. No evidence was found during the survey to suggest a single instance of ineffective simulator training. It is possible, however, that a systematic, objective determination of the effectiveness of each of these programs might indicate their strengths and weaknesses, and the information thus obtained could be used to increase their effectiveness.

III. PRINCIPAL FACTORS INFLUENCING SIMULATOR TRAINING EFFECTIVENESS

INTRODUCTION

The primary objective of the research described in this report was to identify the principal factors which influence the effectiveness of Air Force simulator training. The approach adopted in seeking to identify these factors was two-fold: (a) to survey selected Air Force simulator training activities in order to identify factors operating upon or within those activities to influence their effectiveness; and (b) to search the simulator training research and technical literature to identify factors that were likely influences upon simulator training. This section of the report identifies the factors found during the survey and literature search.

The Survey

The survey encompassed the ten Air Force simulator training activities identified in Section I. The survey included both inspection of the simulators involved in those activities and interviews with simulator instructors and trainees and with ISD and supervisory personnel responsible for the development and conduct of simulator training programs. During the survey, extensive inquiries were made concerning simulator training requirements, procedures, and practices, and attempts were made to relate the responses obtained to the effectiveness of simulator training at each of the bases included in the survey.

The evidence concerning simulator training effectiveness obtained during the survey is described earlier in this report. In general, that evidence was not such that simulator training effectiveness could be related directly to specific characteristics of the simulator training activities surveyed. As has been noted above, the interests of Air Force personnel responsible for the conduct of simulator training activities tend to be primarily concerned with determining the effectiveness of the particular training programs for which they are responsible rather than with the conduct of research to investigate factors that might tend to influence the effectiveness of their training programs.

Thus, while a number of factors were identified during the survey that appeared to be at least potential influences upon the effectiveness of the simulator training activities surveyed, the magnitude, or even the direction in some cases, of their influence could only be hypothesized. Confirmation that they do in fact influence simulator training thus rests largely upon indirect evidence. Such evidence is to be found primarily in the research and technical literature related to simulator training, rather than in controlled studies of simulator training effectiveness within the operational training activities surveyed.

The Literature Search

A summary of simulator training studies by Puig[1] indicated that simulator training effectiveness has increased markedly since World War II. Some of the increase undoubtedly can be attributed to advances in engineering and instructional design technologies. Simulation engineers now have the technology available to build simulators that more nearly satisfy Thorndike's common elements design hypothesis, and instructional system designers have learned how to zero in on tasks to be trained. But much of the increase has come about as a result of research and experience with simulators in operational training settings. The present project included a search of the literature that described that simulator training research and experience.

In spite of the large number of simulator effectiveness studies to be found in the research and technical literature, it is evident that there remains much to be learned about factors influencing training with these devices. A number of factors have been nominated in the literature as influences upon simulator training effectiveness, but many of those nominations have been based on inference rather than experimental evidence.

In their review of simulator research, Muckler, Nygaard, O'Kelley, and Williams[2] noted that many studies compound the influence of several potential influences, such as training program content, instructional technique, and instructor qualification, into a single independent variable so that realized training benefits can be attributed only to the unique combination of those influences in a particular study. Even in the few experimental investigations that isolate assumed influences, the results must be interpreted cautiously, because they address unique training requirements and the studies have seldom been replicated.

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[1] Cited in Micheli, G. Analysis of the Transfer of Training, Substitution and Fidelity of Simulation of Training Equipment. TAEG Report 2, Naval Training Equipment Center, Orlando, FL, 1972.

[2] Muckler, F. A., Nygaard, J. E., O'Kelley, L. I. and Williams, A. C., Jr., Psychological Variables in the Design of Flight Simulators for Training. Technical Report WADC 56-369, Aerospace Medical Laboratory, Wright-Patterson AFB, OH, 1959.

Definitive data could not be found in the literature that would permit the quantification of the influence of all factors noted during the survey of Air Force training which may be potential influences upon simulator training effectiveness. In fact, the mere identification of most such factors rests upon inference, conjecture, and untested hypotheses. The absence of hard data obviously cannot justify suspected factors being ignored, however. Where inferences can be made and supported by consensus, factors believed to influence simulator training must be taken into account by those responsible for simulator design and use, unless evidence can be assembled to refute those inferences.

Methodological Problems

The methodological problems involved in identifying factors that influence simulator training effectiveness cannot be overcome easily. Suspected factors can seldom be examined in isolation. It is difficult, for example, to determine experimentally the relative value of a remote simulator instructor station vs. an on-board or in-the-cockpit station, even if a suitably designed simulator were available for the research, because to use each station to its best advantage would necessitate having two methods of training: one optimized for remoted instruction; the other optimized for on-board instruction. The experiment would thus compare instructor station-training program combinations, not a simulator design feature in isolation from other factors. The training program factor cannot be held constant. It would be inappropriate to compare two simulator designs using a program optimized for only one, or for neither.

The problem of generalizable results is not limited to studies involving operational simulators. Even using equipment designed and dedicated to research, problems arise. For example, to pursue the illustration of instructor station location described above, simulator hardware inflexibility makes it difficult to conduct the necessary research leading to the design of the optimum remote instructor station for experimental comparison with the optimally designed on-board station. Additionally, the on-board station design that is optimum for a single seat, high performance attack aircraft simulator with a visual display may bear little resemblance to the optimized on-board station for undergraduate instrument training in a side-by-side seating helicopter simulator.

FINDINGS FROM THE SURVEY AND LITERATURE SEARCH

The following discussion summarizes the information about factors influencing simulator training obtained during the inspection of Air Force simulators and the interviews with personnel associated with their use. The various factors observed by the writer and/or suggested by the personnel interviewed are described. In addition, relevant information from the research and technical literature is presented in an attempt to assess the probable influence of the factors cited upon the effectiveness of simulator training in the Air Force.

This information is organized according to subject matter, i.e., simulator design, training programs, personnel, attitudes, expectations, and other miscellaneous factors. This organization was adopted as a convenient vehicle to portray the writer's impressions. Decisions to identify a factor as associated with a particular subject matter area were sometimes made arbitrarily. The adopted organization provides a convenient conceptual framework within which to structure a discussion of factors influencing simulator training effectiveness, but it by no means is intended to impose constraints upon the identification of other factors that might be considered by others to influence simulator training effectiveness.

Simulator Design

There are two areas of interest with respect to the influence of simulator design upon transfer of training: fidelity of simulation and design for training. Fidelity refers to whether features of the aircraft and its environment are included in the simulator's design, and the extent to which features that are included represent or duplicate their real world counterparts. Design for training refers to the inclusion in simulator design of features or configurations that facilitate training, but that may bear no particular resemblance to features of the aircraft and environment being simulated.

Fidelity of simulation is often equated with physical correspondence between the device and its real world counterpart. In a discussion of simulator design considerations, however, Smode and Hall[1] emphasize instructional strategies and capabilities and suggest that fidelity has meaning in terms of the process and the realism necessary to promote learning. Design characteristics, they assert, should be defined in terms of assuring transfer of training. In other words, fidelity of simulation is a matter of the relevance of the simulation to the training objectives, not solely a matter of physical correspondence. Bryan and Regan[2] also noted this relationship between fidelity and training when they suggested that simulator design can omit features of the aircraft, even cockpit components with which the pilot might normally interact, if the features are not part of the subject matter of the intended training. This concept of fidelity accounts for the reported training effectiveness of so-called low fidelity devices, such as those made of plywood and photographs,[3] as well as simulators that faithfully reproduce much of the aircraft.

Fidelity of simulation was cited as a factor that influenced the effectiveness of several of the simulator training programs included in the present survey. Some of these simulators, for example, had not been modified to reflect all of the changes that have occurred in the design model aircraft. This was found to be particularly true with respect to avionics and EW/ECM systems. The result has been to reduce the physical correspondence between the simulator and the aircraft to the point, in some instances, that training required to accomplish a mission in the aircraft cannot be conducted in the simulator. It was noted in most such instances, however, that steps were being undertaken to correct these discrepancies, and thus to increase the range of training activities that can be undertaken in the device. Nevertheless, the almost inevitable lag between the time the aircraft is modified and the time that that modification is incorporated into the simulator appears to affect simulator training effectiveness in two ways: certain performances required in the aircraft cannot be trained in the simulator; and differences between the device and the aircraft detract from simulator training and tend to reduce its perceived value, particularly among trainees who may have unfavorable attitudes toward simulation anyway.

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[1] Smode, A. F. and Hall, E. R. Translating Information Requirements into Training Device Fidelity Requirements. In Proceedings Human Factors Society 19th Annual Meeting. Human Factors Society, Santa Monica, CA, 1975.

[2] Bryan, G. L. and Regan, J. J. Training System Design. In Van Cott, H. P. and Kinkade, R. G. (Ed.), Human Engineering Guide to Equipment Design (Rev. ed.). Washington: Government Printing Office, 1972.

[3] Prophet, W. W. and Boyd, H. A. Device-Task Fidelity and Transfer of Training: Aircraft Cockpit Procedures Training. Technical Report 70-10, Human Resources Research Organization, Alexandria, VA, July 1970.

Design for Training: The Smode and Hall concept of fidelity is of particular interest with respect to simulator features not modeled after the aircraft. These features that are concerned primarily with application of principles of learning to the training process include freeze, adaptive training, prompting and cueing, performance recording and playback, performance measurement, and various instructor station displays and controls. It is generally held that such features improve the conditions under which learning takes place and thereby facilitate the attainment of training objectives.[1] Therefore, they are factors to be considered in judging the fidelity of a device so far as training is concerned.

It is general practice to adopt innovative simulator design features such as those mentioned above on the basis of their apparent utility without subjecting them to experimental scrutiny. For example, the widely used simulator freeze feature was implemented because it was seen as an aid to attaining training objectives and to implementing learning concepts during the instructional process. Similarly, other design decisions are made because the training objectives and planned concepts of simulator employment lead to the analytical conclusion that a particular design is appropriate in preference to others. For example, in the design of the U. S. Air Force simulators for the H-3 and H-53 helicopters and the U. S. Army simulators for the CH-47 and the AH-1 helicopters, the instructor stations were located virtually inside the cockpits of these devices, and certain instructor displays were positioned so that they could be viewed by both the instructor and the trainees in order to facilitate instructor-trainee interactions during key training activities. The training effectiveness of these features probably will never be determined in a transfer experiment for reasons discussed above. Analytically, they are believed to represent effective simulator designs with respect to the training programs and the training objectives being addressed.

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[1] Prophet, W. W., Caro, P. W. and Hall, E. R. Some Current Issues in the Design of Training Devices, 25th Anniversary Commemorative Technical Journal, Naval Training Equipment Center, Orlando, FL, November 1971.

The design of simulators for the FB-111 at Plattsburgh Air Force Base provides an opportunity for an indirect examination of the question of instructor position location. The FB-111 Aircraft Simulator consists of a replication of the positions of the pilot and the bombardier/navigator in the cockpit of the aircraft, these two positions being mounted on a five-axis motion platform. Positions for a pilot instructor and for a bombardier/navigator instructor are provided off the motion platform. In addition to this device, there is a separate FB-111 Bomb/Nav Simulator consisting of a replication of the bombardier/navigator's cockpit position with an adjacent instructor position, neither of which is mounted on a motion platform. The latter device is intended primarily as a part-task trainer in which the bomb/nav tasks are emphasized, whereas the larger simulator is intended for full-mission training involving both FB-111 crew members. A major portion of the mission tasks of the bombardier/navigator can be simulated in either device, however. In the part-task simulator that lacks a pilot position, most pilot tasks can be "simulated" by the instructor, whose position in the device approximates the position of the pilot in the aircraft. Thus the training program and the role and position of the bombardier/navigator instructor in these two devices are quite different.

The limited resources available during the present survey did not permit a comparison to be made of the effectiveness of bombardier/navigator training in these two devices. Nevertheless, several comments were made by instructors at Plattsburgh favoring the on-board instructor position. The bombardier/navigator instructors interviewed, each of whom conducted training in both devices, indicated that, in their judgment, they were able to instruct more effectively in the Bomb/Nav Simulator because they could see what the trainee was doing and could diagnose his difficulties more easily than in the other device. The trainees also expressed a preference for the Bomb/Nav Simulator, commenting that, in it, the instructor was there to help, whereas in the larger simulator, the instructor was "out there plugging in malfunctions." While factors other than simulator design could be operating within the small sample interviewed and might account for such comments, the existence of these two devices presents an opportunity for further examination of this major aspect of simulator design.

The design of the Air Force's C-5 simulator is such that most of the instructing is done by on-board instructors seated near the trainees of interest, i.e., pilot instructor, flight engineer instructor, and navigator instructor. The C-5 simulator also has a remote position from which an additional instructor can provide minor assistance to the on-board instructors related to problem set-ups and can provide voice communications from simulated ground stations. Instruction cannot be conducted from this remote position, however. Comments were made by the on-board instructors about the role of the remote instructor that suggested that the latter's performance was not always of the highest quality. Observation of the remote instructor during a simulator training mission suggested a possible reason for the reported quality of his performance that relates to simulator design: he has too little to do to maintain his attention. For the most part, he has been designed out of the instructional process. Consequently, he tends to become inattentive and thus is prone to make errors.

In the simulator for the F-106 at Castle Air Force Base, where the instructor position is beside the cockpit (no platform motion is involved), the instructors expressed a preference for instructing with the canopy open. It was their feeling that, with the Continuation Training student, the instructor could be more effective when his interactions with the student involved direct observation. They reported that with the canopy open, their interactions with the trainees were more frequent also. It should be noted that similar use of the same simulator in Combat Crew Training at Tyndall Air Force Base was not reported, and the instructors there felt that more effective training could be provided when the canopy was closed, as it is in the aircraft in flight.

The proximity of the F-106 simulator cockpit to the device's instructor console permits the simulator instructor to interact with the trainee when the canopy is open while maintaining access to his controls and displays. With simulators where such proximity does not exist, such as the F-4 and A-7 simulators, very little instruction reportedly takes place during CCT or CT with the canopy open. The instructor using these latter devices occasionally sits in a fold-down jump seat from which he can observe the trainees directly, but the motion platform must be off when the jump seat is occupied, and there are very few controls available there for instructor use. Other differences between F-106 and other simulator training that undoubtedly influence the extent to which the training is conducted with the canopy open include the training syllabi and the availability of other devices such as CPTs in which portions of the training that would benefit most from observation of trainee responses can be conducted.

The construction of separate simulators for each crew station of a multi-crew aircraft, as opposed to construction of a single simulator with each crew station represented, was noted as a likely influence upon simulator training effectiveness. While it makes possible more efficient training of individual crew members, in some instances separate simulators may make training in tasks requiring the coordinated activity of more than one crewman more difficult.

Visual Fidelity. Tasks that cannot be duplicated or even approximated in a device cannot be learned there for subsequent transfer to the aircraft. Therefore, a simulator in which more tasks characterizing flying can be performed has greater potential training effectiveness than one in which fewer such tasks can be performed. For example, a simulator that includes an extra-cockpit visual display would seem to have more effectiveness potential with respect to training tasks requiring visual references than a simulator without such a display.

There has been a number of simulator training studies involving visual displays in which transfer of visual flight skills has been demonstrated. The scenes presented by the displays used in some of these studies are much simpler than scenes viewed from an aircraft. For example, savings in aircraft time required to perform visual reference maneuvers were demonstrated by Flexman, Matheny and Brown[1] in a study using a simulator with a very simple visual display. The display consisted of a line drawing of a runway on a blackboard that was placed in front of the device's cockpit and tilted by an instructor to make the runway change perspective as the device was maneuvered with respect to simulated ground references. The effectiveness of displays consisting of stylized grids and lines has been demonstrated in backward transfer situations during studies of contact analog displays developed for helicopters.[2] Displacement of visual scene elements consisting only of dots and lines was found by Thielges and Matheny[3] to provide sufficient information for the performance of basic aircraft control tasks. Studies such as these indicate that tasks involving aircraft control in relation to extra-cockpit visual information can be practiced effectively in simulators with very simple visual scene displays. Such displays can consist of no more than points, lines and geometric patterns arranged in accord with a set of mathematical relationships first described by Gibson.[4]

Several manufacturers currently are marketing displays that employ these simple scene content design concepts. Their displays represent night scenes as patterned points of light on a dark field. These night only visual displays have considerable face validity and have been well received for use in both commercial airlines and military simulator training programs. While part of their acceptance by pilots might be attributed to the relatively large amount of information that has been represented by the light patterns, the use of color, and the addition of textured surfaces in some instances, the research literature clearly suggests that even the simplest of these displays have training value.

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[1] Flexman, R. E., Matheny, W. G. and Brown, E. G. Evaluation of the School Link and Special Methods of Instruction in a Ten-Hour Private Pilot Flight-Training Program. University of Illinois Aeronautics Bulletin No. 8, Urbana, IL, 1950.

[2] Dougherty, D. J. Final Technical Report, JANAIR Contract 4429(00). Joint Army and Navy Aircraft Instrumentation Research (JANAIR) Technical Report No. D288-100-001, Bell Helicopter Company, Fort Worth, TX, 1966.

[3] Thielges, J. R. and Matheny, E. G. Analysis of Visual Discriminations in Helicopter Control. Technical Report 71-13, Human Resources Research Organization, Alexandria, VA, 1971.

[4] Gibson, J. J. The Perception of the Visual World. New York: Houghton Mifflin Company, 1950.

The effectiveness of such simple visual displays has been demonstrated principally with respect to basic aircraft control and approach and landing maneuvers. It is also noted, however, that simulators without an extra-cockpit visual display can be effective in the training of similar visual reference flight tasks. For example, in a study involving a helicopter simulator without a visual display or any other representation of outside visual cues except the aircraft's navigation and attitude instruments, and without any attention during simulator training to extra-cockpit visual cues per se, students trained to fly instrument flight missions in the device qualified in the aircraft under visual conditions more rapidly than did students not receiving the prior device training.[1] In a similar study using a fixed wing simulator without a visual display, a saving in visual flight time required to complete a transition course of approximately 50% of the scheduled course length was obtained.[2] The successful use of the non-visually equipped A-7D simulator at Davis-Monthan Air Force Base to prepare CCT students for the first visual solo flight in the aircraft was mentioned in an earlier section of this report.

The transfer of skills acquired in a non-visually equipped simulator to an aircraft is consistent with findings of research involving the conduct of instrument flight training in aircraft prior to visual flight training. These so-called "instruments first" studies have consistently demonstrated that instrument flight skills facilitate the acquisition of visual flight skills. The substitution of a simulator for an aircraft as the locus for instrument training should be expected to result in similar training benefits.

It is not indicated by these studies' results that visual displays have no training value, that all visual discriminations pilots need can be learned in simulators without visual displays, or even that any visual flight skills can be fully developed in a simulator without a visual display or practice of visual tasks in an aircraft. They do suggest, however, that many tasks performed in response to extra-cockpit visual stimuli in the aircraft can be learned, at least in part, through practice in response to stimuli in a simulator without an outside display. Conventional cockpit instruments provide an analog display of the visual world outside the cockpit, so a pilot flying instruments is responding to stimuli analogous to those available to the pilot flying visually. Similarly, single-window computer generated visual scene displays are analog displays which are viewed by the pilot trainee through the simulator wind screen. An instrument panel display that presented the same information inside the cockpit instead of through the wind screen probably would be equally effective from the training standpoint.

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[1] Caro, P. W., Isley, R. N. and Jolley, O. B. Mission Suitability Testing of an Aircraft Simulator. Technical Report 75-12, Human Resources Research Organization, Alexandria, VA, June 1975.

[2] Caro, P. W., Isley, R. N. and Jolley, O. B. Research on Synthetic Training: Device Evaluation and Training Program Development. Technical Report 73-20, Human Resources Research Organization, Alexandria, VA, 1973.

Even in those situations in which necessary cues cannot be represented adequately by an instrument or analog display, alternatives may exist to the provision of an extra-cockpit visual display for some training. For example, the Air Force has demonstrated significant improvement in the performance of visual flight maneuvers following training in a classroom using 35 mm slides and 8 mm movies.[1] While the scope of the training involved in this line of research has been limited, it does suggest that visual displays can be separated from the simulator altogether for at least a portion of the training required to meet some training objectives.

While there have been numerous studies of the training effectiveness of simulators with extra-cockpit visual displays, few of those studies included a control group in which students were trained in the simulator without using its visual display. In the only study with such a control group known to the present writer that examined pilot performance in the aircraft, following training in a simulator, the results were judged inconclusive by its authors.[2] DeBerg, McFarland, and Showalter,[3] in a study based upon the Simulator-to-Simulator Transfer Model described earlier, examined the effects upon training of adding a visual display to an existing simulator during the simulation of engine failure during takeoff. Their data show an improvement in post-training pilot performance when the visual display was used and the simulator's motion system was employed, but pilot performance when only the visual (i.e., no motion) was used was inferior to performance when neither visual nor motion was employed.

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[1] Smith, B. A., Waters, B. K. and Edwards, B. J. Cognitive Pretraining of the T-37 Overhead Traffic Pattern. Technical Report AFHRL-TR-75-72, Air Force Human Resources Laboratory, Williams AFB, AZ, December 1975.

[2] Young, L. L., Jensen, R. S. and Treichel, C. W. Uses of Visual Landing System in Primary Flight Training. Technical Report ARL-73-26/AFOSR 73-17. University of Illinois Aviation Research Laboratory, Savoy, IL, 1973.

[3] DeBerg, O.H., McFarland, B. P. and Showalter, T. W. The Effect of Simulator Fidelity on Engine Failure Training in the KC-135 Aircraft. Paper presented at American Institute of Aeronautics and Astronautics Visual and Motion Simulation Conference, Dayton, OH, April 26-28, 1976.

Commercial airlines have reduced aircraft training time following the addition of a visual display to an existing simulator, but some if not all of such reductions resulted from a priori judgments by government agencies, pilot's associations and the airlines themselves concerning increased simulator training effectiveness. Likewise, the amount of flight training included in the C-5A[1] CCT programs at Altus Air Force Base was reduced following the addition of a visual display to that simulator, but the amount of the reduction was based upon a priori judgments, later confirmed by post hoc opinions, rather than by an empirical determination of the increased value of simulator training following addition of the visual display. The assumption that extra-cockpit visual displays increase simulator training effectiveness are so strong that their value is seldom questioned. Validation of their training benefits has not been sought in most cases.

A lack of empirical evidence of the training effectiveness of visual displays cannot be taken as evidence of their lack of effectiveness. There is a consensus that they are effective, particularly for the more complex visual tasks associated with flying, and data to contest that consensus do not exist. Logically, it would appear that an extra-cockpit visual display is an effective way, and possibly the only way in some instances, to present visual information needed for many operational tasks, e.g., formation flight, refueling, delivering certain kinds of weapons, and air-to-air combat. For others, e.g., taxiing, flying traffic patterns, making visual approaches, and performing basic aircraft control maneuvers, it may be effective but inefficient, particularly when cost is taken into consideration.

Regardless of their demonstrated effectiveness (or lack thereof), it has been observed that commercial pilots prefer to train in simulators that have visual displays, and further, that they prefer simulators with displays having a rich scene content, such as that provided by motion picture or TV images of the world as viewed from the aircraft, as opposed to displays composed of points of light on a dark field.[1] Likewise, the Air Force pilots interviewed during the current survey were in agreement that the effectiveness of the non-visually equipped simulators in which they train would be increased by the addition of visual displays. For the most part, these pilots had not had the opportunity to inspect a variety of kinds of displays, so they held no particular preference for one kind over another. Since increased fidelity was frequently cited as the basis for their desire for visual displays in the first place, however, it is likely that they would share with commercial pilots the preference for displays having a rich scene content. If these preferences were reflected in their willingness to undergo training in simulators having such displays, as opposed to their unwillingness otherwise, then the presence of a visual display and the richness of its scene content can influence simulator training effectiveness.

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[1] The C-5 simulator at Altus Air Force Base was the only simulator included in the current survey with a visual display. The evaluation of the effectiveness of training with this device is discussed in Section II.

Apart from the preferences of pilots regarding display richness, and the possible consequences of such preferences upon simulator use, the training research literature suggests strongly that quite simple visual displays may have as much training value as those rich in scene content. Relevant information must be displayed, of course, but it sometimes appears that unnecessary emphasis is placed upon designing visual displays that look like the "real world" viewed through the aircraft's wind screen. There may be a need for such a level of scene fidelity with respect to some training requirements, but more often, it is likely that the display design requirements are more responsive to fidelity goals than to training necessities. In designing visual displays for simulators, it would be less costly to seek simple displays whenever simple ones are responsive to well defined training requirements. Smode's and Hall's[2] assertion that fidelity of simulation is a matter of the relevance of the simulation to the training objective applies to the design of visual displays as well as to other simulator components.

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[1] Personal communication, R. A. Waldrop, American Airlines, 1975.

[2] Smode, A. F. and Hall, E. R. Translating Information Requirements into Training Device Fidelity Requirements. In Proceedings Human Factors Society 19th Annual Meeting. Human Factors Society, Santa Monica, CA, 1975.

Motion Fidelity. Although motion simulation represents a significant portion of the cost of simulator procurement and operation,[1] the investigation of the influence of motion upon transfer of simulator training to operational aircraft has been largely ignored. There were a number of studies of simulator motion in relation to aircraft handling qualities and control during the 1950s and 1960s, but most of them addressed transfer of training only indirectly. The first significant published transfer of training study of the effectiveness of simulator motion upon subsequent performance in flight was reported in 1975 by Jacobs and Roscoe.[2]

Jacobs and Roscoe reported that pilot performance in the aircraft did not benefit from the presence of normal washout cockpit motion in the simulator. In that study, training received in the GAT-2 in a two-axis (pitch and roll) normal washout motion condition, compared with training in the same device without motion, resulted in non-significant differences in amount of transfer to the aircraft for those two conditions. There was, however, significant positive transfer for both motion and no-motion conditions. Similar results have been obtained in a U.S. Air Force undergraduate pilot training study involving the more sophisticated six-axis motion system associated with the Advanced Simulator for Pilot Training (ASPT).[3]

The findings in these two recent studies that the presence of motion did not increase simulator training effectiveness is of considerable interest, since there are other studies showing that, at least under some circumstances, motion does influence simulator training. For example, Fedderson[4] reported a slight advantage in favor of a motion simulator trained group over a no-motion group during brief transfer trials hovering a helicopter. More importantly, perhaps, the motion group in his study reached asymptotic performance in the simulator more rapidly, suggesting that simulators with motion may provide more efficient training. A recent U.S. Air Force study of pilot responses to engine failure in a simulated transport-type aircraft found that training is more effective when motion is added to a simulator with a visual display than when the same simulator and visual are used without motion.[1]

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[1] Cohen, E. Is Motion Needed in Flight Simulators Used for Training? Human Factors, 1970, 12, 75-79.

[2] Jacobs, R. S. and Roscoe, S. N. Simulator Cockpit Motion and the Transfer of Initial Flight Training. In Proceedings Human Factors Society 19th Annual Meeting. Human Factors Society, Santa Monica, CA, 1975.

[3] Woodruff, R. R. Full Mission Simulation in Undergraduate Pilot Training: An Exploratory Study. Technical Report AFHRL-TR-76-84, Air Force Human Resources Laboratory, Williams AFB, AZ, December, 1976.

[4] Fedderson, W. E. The Role of Motion Information and Its Contribution to Simulation Validity. Technical Data Report No. D228-429-001, Bell Helicopter Company, Fort Worth, TX, 1962.

Further, there is evidence that pilot performance differs as a function of the presence or absence of motion. For example, Perry and Naish[2] found that pilots respond to external forcing functions such as side gusts more rapidly, with more authority, and in a more precise manner in a simulator with motion and visual cues than when only visual cues are present. NASA researchers[3] found that the correlation between pilot performance in an aircraft and in a simulator increased with the addition of simulator motion cues where such cues help the pilot in coping with a highly damped or unstable vehicle or a sluggish control system, or under some circumstances, where the control system is too sensitive. Where the aircraft is easy to fly, however, as is the case with the aircraft used in the Jacobs and Roscoe study (Piper Cherokee) and in the Air Force ASPT study (T-37), motion may have no effect. In another NASA study[4] of the effects of simulator motion on pilot's performance of flight tracking tasks, the results from a moving base flight simulator resembled the results from flight much more than did those from a motionless simulator. In a British study, Huddleston and Rolfe[1] reported that the presence of simulator motion produced patterns of control response more closely related to those employed in flight. That is, using simulators without motion, experienced pilots were able to achieve acceptable levels of performance, but their patterns of control response showed that their performance was achieved using a strategy different from that used in a dynamic training environment. Research at the University of Illinois related to instrument display design found that the quality of the simulator motion involved affected pilot responses to display types differentially, with inappropriate banking motions interfering with command flight path tracking.[2]

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[1] DeBerg, O. H., McFarland, B. P. and Showalter, T. W. The Effect of Simulator Fidelity on Engine Failure Training in the KC-135 Aircraft. Paper presented at American Institute of Aeronautics and Astronautics Visual and Motion Simulation Conference, Dayton, OH, April 26-28, 1976.

[2] Perry, D. H. and Naish, J. M. Flight Simulation for Research, Journal of the Royal Aeronautical Society, 1964, 68, 645-662.

[3] Rathert, G. A., Jr., Creer, B. Y. and Sadoff, M. The Use of Piloted Flight Simulators in General Research. Report 365, Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization, Paris, France, 1961.

[4] Douvillier, J. G., Jr. Turner, H. L., McLean, J. D. and Heinle, D. R. Effects of Flight Simulator Motion on Pilots' Performance of Tracking Tasks. Technical Note NASA-TN-D-143, National Aeronautics and Space Administration, Washington, DC, 1960.

Thus, numerous studies provide evidence that the presence of motion, i.e., movement of the platform upon which the simulator cockpit rests, does affect performance in the simulator. Not only can motion affect learning rates, but the performance of the pilot in the presence of motion may be different than it would be in the absence of motion. With motion, his simulator control responses to external forcing functions appear to be more rapid and accurate and more like responses used to control the aircraft in flight. While it cannot be concluded from these studies that simulator motion during training will enhance subsequent performance in the aircraft, they do suggest that simulator motion can affect the acquisition of skills in the simulator. These effects of motion upon performance in the simulator have been demonstrated under controlled experimental conditions that tend to make it unlikely that the noted differences in performance could be attributed solely to factors other than the presence of motion during simulator training.

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[1] Huddleston, H. F. and Rolfe, J. S. Behavioral Factors Influencing the Use of Flight Simulators for Training. Applied Ergonomics, 1971, 2.3, 141-148.

[2] Ince, F., Williges, R. C. and Roscoe, S. N. Aircraft Simulator Motion and the Order of Merit of Flight Attitude and Steering Guidance Displays. Human Factors, 1975, 17, 388-400.

The influence of platform motion is not necessarily beneficial, however. Excessive or inappropriate motion, e.g., high levels of simulated turbulence, could make learning less rapid if it were a factor in making the simulator more difficult to control. Likewise, motion that is out of synchronization with visual or other cues could interfere with simulator control if it made trainees ill or presented misinformation to them. For example, it has been reported that the simulator used in the Air Force ASPT study cited above has time lags in the motion system that make the performance of some maneuvers difficult.[1]

In discussing the influence of motion upon pilot performance in simulators, Gundry[2,3] distinguishes between two kinds of motion cues and suggests that they might affect performance differentially. Maneuver motion is that motion that arises within the control loop and results from a pilot-initiated change in the motion of the aircraft in order to change its heading, altitude, or attitude. Disturbance motion, on the other hand, arises outside the control loop and results from turbulence or from failure of a component of the airframe, equipment or engines that causes an unexpected (to the pilot) motion of the aircraft. Matheny[4] made a similar distinction in a study in which he identifies aircraft motion as resulting from external forcing functions or from input into the aircraft controls.

The reason that platform motion can result in quicker, more accurate simulator control probably is that the disturbance component of that motion resulting from simulated turbulence or equipment failure can provide more rapid and relevant alerting cues about forces acting upon the aircraft than could be obtained from other cue sources. Maneuver motion does not fulfill an alerting function, because it results from pilot-initiated control movements. Research involving maneuver motion, Gundry states, indicates that this component of platform motion has little effect upon the control of an aircraft whose flight dynamics are stable. For unstable vehicles, however, the presence of maneuver motion will allow the pilot to maintain control even in flight regions where control by visual cues alone would be impossible. Thus, disturbance motion permits more rapid and accurate aircraft control under all flight conditions in which such motion is appropriate. Maneuver motion, however, improves aircraft control only when the aircraft is unstable.

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[1] Hutton, D. P., Burke, D. K., Englehart, J. D., Wilson, J. M., Romaglia, F. J. and Schneider, A. J. Project No. 2235, Air-to-Ground Visual Simulation Demonstration Final Report, Volume 1. Aeronautical Systems Division, Simulator SPO, Wright-Patterson AFB, OH, October 1976.

[2] Gundry, J. Man and Motion Cues. Third Flight Simulation Symposium Proceedings. Royal Aeronautical Society, London, April, 1976.

[3] Gundry, A. J. Thresholds to Roll Motion in a Flight Simulator. Paper presented at American Institute of Aeronautics and Astronautics Visual and Motion Simulation Conference, Dayton, OH, April 26-28, 1976.

[4] Matheny, W. G. Studies of Motion and Visual Interaction in Simulator Design and Application. Final Report LSI, AFOSR-FR-76-1. Life Sciences, Inc., Hurst, TX, September, 1976.

In both the Jacobs and Roscoe and the Air Force ASPT studies cited above, emphasis was upon simulation of maneuver rather than disturbance motion. Since maneuver motion is pilot induced and the aircraft involved in these studies were quite stable, the most likely role of motion was to provide feedback to the pilot. If sufficient feedback were available from other sources such as the aircraft instruments or an extra-cockpit visual display, as likely was the case, the maneuver motion provided in these two studies could not be expected to have a large effect upon simulator training effectiveness, and probably would be ignored altogether by the trainees. Had these two studies examined the influence of disturbance motion resulting from factors outside the control loop, e.g., malfunctions, the results might have been different.

The evidence that disturbance motion may have a large effect upon pilot performance in the simulator and upon his subsequent performance in the aircraft should not be overlooked by personnel making decisions concerning the importance of platform motion in aircraft simulator training. The fact that the influence of such motion was not apparent in two recent transfer of training studies is probably attributable to the absence of a significant disturbance component to the motion involved in those studies. The maneuver motion that was present appears not to have been a significant factor in transfer of training for the undergraduate level trainee in the relatively stable aircraft involved in these studies.

The majority of the simulators included in the present survey had platform motion systems. These were the C-5, the FB-111, the F-4, and the

A-7. Although the contribution of motion to the effectiveness of the CCT and CT activities in which these simulators are used has not been investigated empirically, the perceived value of the platform motion cues they provide was discussed with the Air Force pilots and instructors interviewed. Many of these personnel held strong opinions concerning the probable value of motion. While those opinions were predominantly favorable, there were a few unfavorable ones as well. In all cases, whether favorable or unfavorable, the basis for the opinions expressed was explored by the investigator.

Favorable opinions were difficult to relate to specific aspects of motion simulation and in many cases were considered to be endorsements of the general idea that simulator motion is important because the aircraft moves. Those who were the most enthusiastic in their opinions favoring motion cited motion characteristics of the disturbance type as the primary basis for their positive views, i.e., motions associated with equipment failure, weapons release, buffet and turbulence. Very few pilots expressed strong positive feelings toward maneuver motion--it contributed to realism, but was not cited as specifically related to particular training goals.

The relatively few negative opinions expressed concerning motion were all strongly held, and they involved both maneuver and disturbance motion. In one simulator in which maneuver motion cues lagged noticeably behind instrument displays and tended to be jerky rather than smooth, the motion was viewed as annoying, and pilots using that particular device preferred to train with the motion system inoperative. Apparently, maneuver motion can have little positive value in most simulator training programs, but it can have a negative influence, at least upon pilot attitudes, if it is not representative of comparable motion in the aircraft, e.g., if it lags noticeably the pilot's control input or the cues provided by instruments or visual displays.

Most of the negative comments received during the interviews could be related to disturbance motion--or more precisely, to the absence of disturbance motion cues that the pilots knew to be characteristic of the aircraft simulated. Two examples of this situation were noted, one involving the A-7D simulator and the other involving the C-5A simulator.

A critical condition involving the A-7D aircraft is that labeled "Departure." It is a high angle of attack condition in which the aircraft yaws abruptly and enters an uncontrollable spin. The yaw in this case is a disturbance cue that alerts the pilot to the condition's onset. Training in recovery from the departure is considered of critical importance, but such training in the single-place aircraft is not included in A-7D training for reasons of flight safety. Attempts to provide the desired training in the A-7D simulator at Davis-Monthan Air Force Base have been unsuccessful, reportedly because the yaw motion cues cannot be simulated in that device (it lacks the yaw motion axis).

The A-7D manufacturer has a research simulator, called LAMBS (for Large Amplitude Motion Base Simulator), in which the departure can be simulated with the yaw motion component. All Air Force A-7D pilots have undergone departure recovery training in LAMBS. Pilots who have previously experienced a departure in the aircraft have reported that its simulation in LAMBS is "realistic." Pilots who received training in LAMBS and subsequently experienced a departure in the aircraft credit the motion simulator training for the ease with which they were able to reestablish aircraft control, although such reports are purely subjective. In any event, the disturbance cue provided by LAMBS is well received by Air Force A-7 pilots, whereas the absence of that cue in the Air Force simulator renders departure recovery training in it unacceptable.

One of the A-7D pilots interviewed had recently flown the Navy's A-7E simulator which has a six-axis motion system. That pilot expressed a highly favorable opinion concerning the worth of A-7E simulator training and a clearly unfavorable opinion concerning A-7D simulator training. While there are a number of differences in these two simulators and the manner in which they are used, the extent of motion simulation was singled out as an important difference between the two devices which, in the opinion of that particular pilot, influences training.

The C-5A simulator motion platform, like that of the A-7D, lacks the yaw axis, so the yaw disturbance motion associated with loss of an engine cannot be simulated. Pilots associated with C-5A training at Altus AFB cited this deficiency in the simulator as a negative factor in determining the effectiveness of simulator training for engine losses at low altitude. It was not cited as a factor in other training operations, including operations that involve yaw maneuver motion, however. Thus, where yaw could be considered a disturbance motion, it was perceived to be needed for training;

where it could be considered a maneuver motion, it was not perceived as important.

The C-5 simulator at Altus has a visual display, and the yaw of the aircraft associated with engine loss is reflected in the visual scene. The pilots indicated that the visual yaw cue alone was insufficient, in their opinion, when engine loss occurred during landing and takeoff maneuvers. They felt that pilots in the simulator responding to visual cues were much slower in initiating corrective action than they were in the aircraft where motion provides an early and more pronounced alert that a disturbance has occurred.

The influence of platform motion upon transfer of simulator training has not been clearly established by the data available at the present time. It has been demonstrated that motion can affect pilot performance in the simulator in ways that may make his performance in the simulator more like his performance in the aircraft, but it has not been shown that simulator motion enhances his subsequent performance in the aircraft. The two studies that have addressed the question of transfer directly did not support a conclusion that motion is needed. Likewise, there is no consensus among pilots as to the need for motion in simulator training.

The distinction made by Gundry between maneuver and disturbance motion is useful in attempting to understand both the prior research on motion and the reactions of pilots to the motion component of aircraft simulators. It appears that more attention has been paid in the design of current simulators to maneuver motion than to disturbance motion. Emphasis has been upon providing in a simulator the motion cues associated with well-coordinated pilot control inputs, scaled down to the limits of travel and accelerations of the motion platform. Since most training and operational aircraft are relatively stable, this kind of motion simulation may be of very little potential value in training. It might be more beneficial from the training standpoint to provide the motion cues associated with disturbances to the aircraft not originated by the pilot, and then only at their initial onset values, so that he could learn to respond specifically to such cues rather than learning to respond to visual or other cues that occur later in time.

The area of motion simulation is in need of further investigation. Future studies of motion should concentrate upon specific motion cues of a disturbance nature that can be related to specific training objectives. If motion is to have an influence upon simulator training effectiveness, it would appear that such an influence will be found in critical flight maneuvers, not in routine maneuvers performed under optimum flight conditions.

Handling Characteristics

None of the simulators included in the present survey was new, and most were designed from one to three decades ago and employ analog computational technology. Consequently, the extent to which the handling characteristics of those simulators approximate the characteristics of the aircraft being simulated varies widely, with the older, analog devices being considered less like the aircraft than the newer devices. Many of the pilots interviewed commented unfavorably upon the handling characteristics of the simulators in which they were training and expressed views that related the "unrealistic" handling characteristics to limitations upon the device's training effectiveness. In fact, the general view was that a device that did not realistically represent the aircraft was useful only as a procedures trainer in which non-flying tasks could be practiced.

The literature on transfer of training does not fully support these pilot opinions, although supporting views have been expressed by an earlier reviewer.[1] When the simulation algorithm grossly distorts the character of the simulation, as, for example, when the simulator includes an unrealistic control gain, a small negative effect upon transfer of training has been demonstrated.[2] On the other hand, two studies in which the correspondence in control pressures between the simulator and the aircraft was varied concluded that transfer was not affected by large differences in control pressure.[1,2] Instead, transfer depended more upon correspondence between the pattern of control movements required in the simulator and in the aircraft than upon the amount of control force required. Although varying the control pressures affected the ease with which trainees learned to control a device, its transfer of training value was unaffected. Where the correspondence between the device and the aircraft is gross, however, as was reported for one device in which forward pressure on the wheel resulted in a climb configuration,[3] simulator effectiveness undoubtedly will suffer.

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[1] Gerathewohl, S. J. Fidelity of Simulation and Transfer of Training: A Review of the Problem. Report No. AM 69-24, Federal Aviation Administration Office of Aviation Medicine, Washington, DC, December 1969.

[2] Muckler, F. A., Obermeyer, W. H., Hanlon, W. H. and Serio, F. P. Transfer of Training With Simulated Aircraft Dynamics: II. Variations in Control Gain and Physical Characteristics. WADD Technical Report 60-615 (II), Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, December 1961.

Although, in the extreme case, simulator response characteristics unlike those of the aircraft can produce negative transfer of training, there is little evidence that the simulator must precisely duplicate the feel of the aircraft in order to be effective. It is possible, however, that even minor dissimilarities in feel or response could lead to the same kinds of potential problems found in simulators without motion, i.e., lower correlation between simulator and flight performance, particularly where the more difficult to fly aircraft are concerned. The more likely influence of poor correspondence between the simulator and the aircraft is upon the attitude of the personnel involved. Pilots have resisted, and most likely will continue to resist, using a simulator that does not "feel" like the aircraft. In fact, aircraft "feel" has become a principal criterion for simulator design.[4]

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[1] Matheny, W. G., Williams, A. C., Jr., Dougherty, D. J. and Hasler, S. G. The Effect of Varying Control Forces in the P-1 Trainer Upon Transfer of Training to the T-6 Aircraft. Technical Report HRRC-TR-53-31, Human Resources Research Center, Goodfellow AFB, TX, 1953.

[2] Wilcoxon, H. C. and Davy, E. Fidelity of Simulation in Operational Flight Trainers, Part II: The Effect of Variations in Control Loadings on the Training Value of the SNJ OFT. Technical Report SPECDEVCEN999-2-36, Special Device Center, Port Washington, NY, January 1954.

[3] Military Potential Test of Fixed Wing Basic Instrument Trainer 2-B-12A. U. S. Army Aviation Test Board Report of Test USATECOM Project No. 4-3-5150-01-9, U. S. Army Aviation Test Board, Fort Rucker, AL, 1963.

[4] Catron, R. L. A New Approach for Establishing Aerodynamics Performance of Flight Trainers. 8th NTEC/Industry Conference Proceedings. Naval Training Equipment Center, Orlando, FL, November 1975.

A General Conclusion Concerning Design

Understanding of the relation of simulator design features discussed above to simulator training effectiveness is quite limited. It is clear that designing a simulator to be used for training is not entirely a matter of duplicating an aircraft. Instead, it appears to be a matter of providing a learning environment in which precisely specified training objectives may be addressed. If a particular feature of the aircraft and its physical environment is necessary to the performance of a particular task in flight, then that feature, whether it is a dimension of motion, an ECM panel, or a peculiar response characteristic, must be represented in some fashion in the simulator if the device is to be used to practice or learn such a task. If the task can be performed or approximated in a simulator that lacks a particular feature of the aircraft, then that feature may have little or no influence upon simulator effectiveness for the learning of that task. The physical correspondence between the simulator and the aircraft is probably more related to cost, as Miller[1] indicated almost two decades ago, than to training effectiveness. If the degree of correspondence between the device and the aircraft is relevant to the objectives of the intended training, training in the simulator can be made effective; whether it is or not is a matter related to other factors.

Training Programs

Frequent note has been taken of the influence upon training effectiveness of the manner in which a simulator is used. Yet, the literature is full of reports of situations in which the importance of training program design and execution seemed to be ignored.[2,3] Although there is an increasing emphasis upon effective use of device, instances continue to be encountered in which simulators are misused or are used inefficiently by almost all military and civilian pilot training agencies. Even the current research literature contains reports of simulator effectiveness studies in which participating instructors were permitted to conduct training in nonstandardized ways.

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[1] Miller, R. B. Psychological Considerations in the Design of Training Equipment, Technical Report WADC TR-54-563, Wright Air Development Center, Wright-Patterson AFB, OH, December 1974.

[2] Hall, E. R., Parker, J. F., Jr. and Meyer, D. E. A Study of Air Force Flight Simulator Programs. Technical Report AMRL-TR-67-111, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1967.

[3] Casperson, R. C. and Channell, R. C. Use of the Operational Flight Trainer. Technical Report NAVTRADEVCEN 1734-00-1, Naval Training Device Center, Port Washington, NY, May 1957.

To list all training program design and execution variables that potentially influence simulator training effectiveness would be an almost interminable task. Any of the numerous textbooks on human learning will provide a source for identification of variables that influence learning and performance, e.g., schedules of reinforcement, meaningfulness and difficulty of material to be learned, size of learning blocks, anticipatory set, and knowledge of results. Flexman, Matheny, and Brown[1] have shown how such variables can be employed to increase simulator and flight training effectiveness.

During the current survey of Air Force simulator training activities, a number of training program features were noted that might be suspected to affect simulator training effectiveness. For example, it is a common practice in Air Force CCT programs to alternate instructional periods between the simulator and the aircraft. While the specific pattern of alternation varies from program to program, a typical pattern would involve a period of simulator training only, followed by a period during which consecutive missions might alternate between the simulator and the aircraft, and finally, a period during which all training missions are conducted in the aircraft. The emphasis upon early training in the simulator and later training in the aircraft seems reasonable and probably is dictated in part by the availability of both simulators and aircraft, as well as the "realism" of the simulators themselves. Of interest in such programs, however, is the question whether the alternation between two training vehicles, particularly in those cases in which the simulator might be judged "unrealistic," might influence the effectiveness of simulator training.

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[1] Flexman, R. E., Matheny, W. G. and Brown, E. G. Evaluation of the School Link and Special Methods of Instruction in a Ten-hour Private Pilot Flight-Training Program. University of Illinois Aeronautics Bulletin No. 8, Urbana, IL, 1950.

The sequencing of simulator and aircraft training has been suggested elsewhere as a factor that could influence the effectiveness of simulator training. Smode, Hall and Meyer[1] concluded that the evidence concerning the influence of sequencing was inconclusive, although they suggested there might be circumstances in which a sequence that alternates between simulator and aircraft would be beneficial. Meister, Sullivan, Thompson and Finley[2] presented data that suggest that switching from the aircraft to the simulator reduced performance in the simulator on the following sessions, resulting in a training inefficiency. From a purely economic standpoint, it would appear desirable to train first in the less expensive (presumably) simulator and transfer that training or resultant performance to the aircraft. While there may be some interactive effects between the sequence, the manner in which the device is used, and the design of the device that could influence effectiveness, it would appear quite likely that training in the aircraft before the full benefit of the simulator has been realized with respect to a particular task would tend to reduce the overall efficiency of the simulator-aircraft training program. In an unpublished, non-Air Force effort that illustrates this view, a fifty training hour program in which the simulator was used prior to training in the aircraft became a sixty training hour program when the sequence was changed to mix simulator and aircraft training, although other procedural changes were introduced concurrently that could have contributed to the resulting inefficiency.

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[1] Smode, A. F., Hall, E. R. and Meyer, D.E. An Assessment of Research Relevant to Pilot Training. Technical Report AMRL-TR-66-196, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1967.

[2] Meister, D., Sullivan, D. J., Thompson, E. A. and Finley, D. L. Training Effectiveness Evaluation of Naval Training Devices Part II. A Study of Device 2F66A (S-2E Trainer) Effectiveness. Technical Report NAVTRADEVCEN 69-C-0332-2, Naval Training Device Center, Orlando, FL, 1971.

Training program content is an obvious influence upon simulator training effectiveness. A dynamic flight simulator used only as a procedures trainer, for example, is not being used effectively, and transfer of training is not good among students who must learn to do one thing in a simulator and something else in an aircraft, an unintended consequence that could possibly result from continued use of obsolete simulators such as the F-4 and B-52 simulators examined during the current survey.

Other potential problems related to the content of simulator training were noted during the survey. In several CCT and CT programs, for example, non-usable information included in the training appeared to be having a negative influence upon simulator training effectiveness because of time being devoted to it rather than to other, more important information. Often, in the course of a training mission in one of these programs, it was reported that students ask questions about the aircraft that, while of passing interest, are not relevant to the training objectives being addressed. If the instructor could answer the question (instructors typically take pride in being able to supply upon demand the most obscure and, from the cockpit at least, unusable bits of information about the aircraft), he would do so, thus possibly reducing training effectiveness by overloading the student with information that he would not be able to use while performing as an aircrew member and additionally reducing the training time available to provide more useful information. Presumably, as on-going Air Force ISD efforts are completed, the amount of non-usable information in such programs will be reduced.

Instances were also noted in which the subject matter addressed in a simulator training program did not appear appropriate to the features of the simulator. In one such instance, it was reported that the questionable subject matter was added at the direction of a commander not familiar with the simulator in question. The consequence was that the effectiveness of simulator training was reduced, at least for the time during which the inappropriate activity was in progress. In such a situation, the ineffective training program content might be attributed more appropriately to the simulator training personnel who rigidly carried out the instruction without attempting to inform the commander of the limitations of the device, than to the commander who attempted to improve the performance of his pilots but was not given adequate feedback concerning his attempts to achieve that purpose.

In spite of the potential training advantages simulators offer over aircraft, there is a tendency in some simulator training programs to ignore those advantages and treat simulators as though they were aircraft. While this practice reflects a favorable attitude toward simulators, it may sometimes reduce simulator effectiveness simply because it preserves some of the disadvantages of the aircraft as a training vehicle. The scheduling of long training periods in the simulator because missions in the aircraft being simulated are necessarily long is an example of such a practice. Another example, reported by personnel at one base visited, was the requirement that all debriefing activity be deferred until after the mission rather than to lose valuable simulator time telling students what they may have done right or wrong in the simulator. While such a practice may have merit in several respects, it fails to take full advantage of the ease with which a simulated mission can be interrupted in order to give trainees feedback concerning performance and the benefits in terms of learning efficiency such a procedure would present.

The duration of a training period in the simulator was cited by a number of the personnel interviewed as a significant factor in simulator training effectiveness. To a degree, their judgments as to optimum period length was a function of the type of aircraft/mission being simulated. Pilots of the small-crewed fighter aircraft that engage in high intensity missions prefer shorter periods than do those of larger-crewed transports and bombers who typically engage in less intensive missions. Where simulator training consisted of high intensity activities such as frequent systems failure, regardless of aircraft type or other considerations, pilots suggested that training periods of from 90 to 120 minutes duration are, in their judgment, of more value than either shorter or longer periods. The tendency to judge the validity of simulator training program period length by comparing it to aircraft missions would appear to have little merit and to lead to reduced training efficiency where the period is of such duration that fatigue can become a factor affecting simulator training effectiveness. Unfortunately, there is no directly applicable research data that can be used as a basis for specifying the optimum duration of a simulator training mission.

The schedule of training activities, that often was designed to optimize use of training resources, could also be a factor affecting simulator training effectiveness under some circumstances. For example, one instance was cited by a group of trainees in which a 4½-hour simulator training mission was completed at midnight, and its post-mission debriefing was completed at 3:00 a.m. The effectiveness of such a long training mission might be questioned purely on the basis of probable trainee fatigue, as could the contiguous three-hour debriefing, although, as indicated above, there is no directly relevant data concerning optimum length of such training activities. Additionally, the efficiency of training at such hours of the morning might be questioned on the basis of available information concerning diurnal rhythms. To compound the possible loss of effectiveness of such a training schedule, these same students reportedly were scheduled for another simulator training mission at 9:00 a.m. It is understood that such tight scheduling of simulator training is not common, however.

There are a number of other training program factors that influence the efficiency of simulator training, although not necessarily its effectiveness. For example, it has also been reported that simulator training presented in the context of simulated mission activities, as opposed to abstract training exercises, tends to be more effective,[1] and the literature on learning and forgetting suggests that behavior learned within such a meaningful context will be less quickly forgotten.[1] Several anecdotes were cited by aircrews interviewed that support these research findings. Other factors include the amount of simulator training, the sequence in which instruction is conducted in the simulator, the use of individual (as opposed to group) pacing, training to specified criterion levels (as opposed to training for fixed time periods), and the extent to which simulator training includes tasks that can be learned more efficiently in the aircraft. Smode, Hall and Meyer[2] pointed out a decade ago that little was known about how to manipulate such factors to best advantage. That observation is still valid.

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[1] Caro, P. W. An Innovative Instrument Flight Training Program. Paper No. 710480, Society of Automotive Engineers, New York, 1971.

Personnel

Simulator training involves trainees and instructors. Both categories of personnel represent potential influences upon effectiveness. The most obviously relevant considerations with respect to both are their qualifications and prior experience, but occasionally other variables are suggested. For example, Meister, Sullivan, Thompson, and Finley[3] found a difference in the effectiveness of one simulator training program for student and operational pilots vs. reservists. The difference could also be attributed to considerations such as fatigue and stress, factors which probably account for many unexpected findings in learning studies. The present report will discuss only the more obvious personnel factors.

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[1] Jenkins, J. J. Remember That Old Theory of Memory? Well Forget It! American Psychologist, 1974, 29, 785-795.

[2] Smode, A. F., Hall, E. R. and Meyer, D. E. An Assessment of Research Relevant to Pilot Training. Technical Report AMRL-TR-66-196, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1967.

[3] Meister, D., Sullivan, D. J., Thompson, E. A., and Finley, D. L. Training Effectiveness Evaluation of Naval Training Devices Part II. A Study of Device 2F66A (S-2E Trainer) Effectiveness. Technical Report NAVTRADEVCEN 69-C-0332-2, Naval Training Device Center, Orlando, FL, 1971.

Trainees. All investigations of human learning are subject to the influences of task related aptitudes of the learners. Aptitudes are defined in terms of learning efficiency, and high aptitude students learn a given task more rapidly or to a greater degree than do low aptitude students. Where the training program involves fixed amounts of simulator training time, high aptitude students learn more tasks to transfer to the aircraft; where training is to fixed performance levels and training time varies, high and low aptitude students achieve about equally, but high aptitude students require less training time in the simulator. A measure of simulator training efficiency such as the Transfer Effectiveness Ratio[1] will yield a higher value for high aptitude students, but this does not indicate that the simulator training program is more effective with such students. It is probably equally effective with both groups of students, but training time in the device will be shorter for one than for the other. Thus, while high aptitude students learn more efficiently, aptitude per se is not believed to be an influence upon simulator training effectiveness.

The influence upon simulator training effectiveness of level of trainee skill or amount of prior flight experience is frequently questioned. Many military pilots and managers, including some of those interviewed during the present survey, acknowledge that simulators provide appropriate training for the airlines, where the trainees are highly experienced, but insist that the devices cannot be relied upon as extensively to train less experienced military pilots, particularly those with fewer than about 1,000 hours flight time. The skills possessed by these two groups of trainees do differ, qualitatively as well as quantitatively, and the tasks for which they undergo training often are not identical. Therefore, the training they receive should not necessarily be identical if it is optimally designed to meet their respective training needs, and the characteristics of the simulators involved in their training might vary as well. It does not follow, however, that simulator training can be appropriately designed and conducted for one experience level trainee but not for another. In fact, the experimental evidence does not support the contention that simulator training effectiveness is influenced by level of trainee experience in isolation from other factors. After reviewing a large number of transfer of training studies, Micheli[1] concluded that flight training devices are effective for both neophyte pilot trainees and airline pilots. Further, Brictson and Burger[2] found that simulator training administered to both low- and high-time pilots was effective for both groups, although it reduced the differences in performance between the two groups during subsequent carrier landing training and in their respective attrition rates.

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[1] Povenmire, H. K., and Roscoe, S. N. An Evaluation of Ground-Based Flight Trainers in Routine Primary Flight Training. Human Factors, 1971, 13, 109-116.

One trainee-related consideration that possibly influences simulator training effectiveness is proficiency at the time of simulator training. A Continuation Training program, particularly one not based upon proficiency as was the case with all of the CT programs included in the current survey, will be of less value for pilots who fly operational missions daily than for pilots assigned to staff positions whose flying opportunities are limited. A given training program can be effective for a pilot whose proficiency is low, but ineffective for a proficient pilot because of the performance proficiencies and deficiencies associated with each.

Crew position is another factor that probably influences the effectiveness of some of the simulator training programs included in the current survey. The Weapons Systems Officer in the F-4E Continuation Training program at Eglin, for example, appears to derive more training benefits from the F-4E simulator than does the pilot. Two factors that appear to influence this apparent difference are: (1) the pilots are reportedly proficient in most of the syllabus missions before engaging in simulator training by virtue of having flown similar missions in the aircraft; and (2) the WSOs are able to practice syllabus tasks in the simulator that they cannot practice in the aircraft. These tasks include operation of EW equipment that cannot be operated in the aircraft for security reasons and performing intercepts to develop levels of proficiency not attainable during their limited training and operational flights in the aircraft.

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[1] Micheli, G. Analysis of the Transfer of Training, Substitution and Fidelity of Simulation of Training Equipment. TAEG Report 2, Naval Training Equipment Center, Orlando, FL, 1972.

[2] Brictson, C. A. and Burger, W. J. Transfer of Training Effectiveness: A-7E Night Carrier Landing Trainer (NCLT) Device 2F103. Technical Report NAVTRAEQUIPCEN 74-C-0079-1, Naval Training Equipment Center, Orlando, FL, August 1976.

Instructors. After reviewing the literature on the flight instructor, Smode, Hall and Meyer[1] concluded that there is no empirical basis for the notion that experienced pilots make better in-flight instructors than inexperienced pilots. The same conclusion can be extrapolated to training in the simulator. While the evidence is skimpy, it appears that even personnel with no flight experience can be trained to be effective simulator instructors. For example, in a simulator training study comparing an instructor with several thousand hours military instructor-pilot experience, a recent flight training program graduate, and a non-rated individual with a few hours dual instruction but no other aeronautical experience, no significant differences were found in the in-flight performance of their students.[2]

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[1] Smode, A. F., Hall, E. R. and Meyer, D. E. An Assessment of Research Relevant to Pilot Training. Technical Report AMRL-TR-66-196, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1967.

[2] Caro, P. W., Isley, R. N. and Jolley, O. B. The Captive Helicopter as a Training Device: Experimental Evaluation of a Concept. Technical Report 68-9, Human Resources Research Organization, Alexandria, VA, 1968.

While no evidence was found during the current survey to refute those findings, they clearly were inconsistent with the views of many of the personnel interviewed. Both proficiency and experience, i.e., total flight time, were frequently cited as having significant influence upon simulator training effectiveness. It was often stated that trainees have little confidence in an instructor who cannot perform well himself.

The chief value of instructor experience appears to be a result of the fact that the Air Force does not provide comprehensive simulator instructor training, so the experiences of the older, more senior instructors enable them to compensate for a lack of training. Instructor behaviors that were cited as illustrative of effective instruction could be developed in all instructors, not just the more senior ones, through an effective program designed to train simulator instructors and to standardize their performance. Examples of effective instructor behaviors cited during the study included (1) the best instructor does not try to teach all he knows, but teaches what he has needed to know in an operational assignment; (2) the good instructor uses the headset, provides ATC simulation, and does other things to simulate situational factors; (3) the good instructor lets the trainee go further before hitting the freeze button; and (4) the good instructor concentrates upon the needs of the trainee, whereas the poor instructor concentrates upon getting through the syllabus.

In spite of the fact that such instructor behaviors are widely viewed as conducive to effective simulator training, no evidence was found during the survey that attempts are made to assure that those behaviors are standardized among simulator instructors. The training provided personnel selected to become simulator instructors varies from base to base, but in no instance during the current review was a simulator instructor training program noted that the present writer would judge to be exemplary. The training provided simulator instructors varies from a "checkout" on the instructor's console during which the location and function of switches and other controls are illustrated and questions are answered by an already qualified instructor, to a more lengthy "practice teaching" program in which a newly selected instructor may spend a week or more observing simulator training and actually conducting training under the supervision and with the assistance of a qualified instructor. In addition, since the personnel involved are flight qualified and often train in aircraft as well as in the simulator, their training typically includes an extended effort to raise their own proficiency and to standardize their performance in the aircraft itself. In some instances, such training includes instruction in the techniques of flight training, lesson planning, and preparation of instructional material. The principal deficiency of these courses, however, is that they do little to provide the instructor specialized knowledge and techniques that will allow him to employ the simulator effectively and efficiently as a training vehicle that has unique capabilities different from those of the aircraft.

Existing training documents related to the use of simulation as instructional tools provide very little guidance to the instructor. Typically, they provide an outline of what tasks will be performed by the pilot trainee during a simulator mission, but they contain little or no information as to how training is to be accomplished, how student performance will be graded, and what performance criteria apply to the trainees, given their particular skill and experience levels.

Unfortunately, not all simulator instructors are well prepared for their job, however. Hall, Parker and Meyer[1] surveyed a number of military training programs and found that non-rated enlisted instructors were ill prepared as compared with pilots, particularly with respect to relevant knowledge of the aircraft. They also noted that pilots were similarly ill prepared with respect to knowledge of the capabilities and limitations of the simulators. Since no transfer data were reported, it cannot be determined whether this factor had an influence upon subsequent in-flight performance in favor of either instructor group. It might be assumed, however, that any simulator instructor will be more effective if he is adequately trained in the use of the simulator.

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[1] Hall, E. R., Parker, J. F., Jr. and Meyer, D. E. A Study of Air Force Flight Simulator Programs. Technical Report AMRL-TR-67-111, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1967.

Muckler, Nygaard, O'Kelly, and Williams[1] observed that in some cases a simulator instructor must provide supplementary information about the in-flight task that might not be available to a non-rated instructor, thus presumably tipping the scale in favor of pilots as simulator instructors. These researchers also noted that instructor ability and fidelity of simulation are related in such fashion that as fidelity increases, the necessary level of instructor ability may decrease, and conversely, as fidelity decreases, instructor ability must increase. This relationship would tend to place the more able instructor in the lower fidelity simulator where a greater amount of supplementary information might be required. It has been observed that just the opposite situation often occurs. The more experienced pilots instruct in high fidelity simulators, while less experienced and non-rated personnel instruct in older, lower fidelity devices.[2]

Another consideration is whether there should be one instructor or two in a simulator training program. That is, is simulator training effectiveness influenced by whether the simulator instructor is also the aircraft flight instructor? While this variable has not been isolated for study, there appears to be an increase in effectiveness when a single instructor is responsible for both simulator and aircraft training. Such an arrangement has been a feature of some simulator training programs for a number of years.[3] One apparent benefit is that the instruction given in the simulator is more compatible with that given in the aircraft when only one instructor is involved, thus reducing any potential negative transfer attributable to instructor-peculiar performance requirements.

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[1] Muckler, F. A., Nygaard, J. E., O'Kelly, L. I. and Williams, A. C., Jr. Psychological Variables in the Design of Flight Simulators for Training. Technical Report WADC 56-369, Aerospace Medical Laboratory, Wright-Patterson AFB, OH, 1959.

[2] Caro, P. W. Aircraft Simulators and Pilot Training, Human Factors, 1973, 15, 502-509.

[3] Williams, A. C., Jr. and Flexman, R. E. Evaluation of the School Link as an Aid in Primary Flight Instruction, Aeronautical Bulletin No. 5, University of Illinois Institute of Aviation, Savoy, IL, 1949.

It often has been assumed that the instructor is an important factor influencing training effectiveness, and such may well be the case. If so, the influence must be attributable to the manner in which the instructor functions, i.e., to the degree of standardization in his administration of the training program. There is insufficient evidence available at this time to attribute the assumed influence to instructor experience or qualification per se, assuming he has undergone an instructor training program appropriate to the instructional task at hand.

Attitudes

It was noted during the current survey that some students entering CCT, particularly those coming directly from Undergraduate Navigator Training where relatively new and well designed simulators are used extensively, have quite favorable attitudes toward simulator training. If they are assigned to a Wing that employs one of the older, "unrealistic" simulators in its CCT, their favorable attitudes quickly change, even to the point that they reportedly dread their scheduled simulator training missions. Instructors in those CCT squadrons who have attempted to point out the relative strength of the simulator training programs report that they feel embarrassed to be defending equipment that the students know to be less than the best, and these same instructors believe they lose credibility in the process. This situation illustrates an apparent relationship between simulator fidelity and trainee attitudes toward simulator training.

It has been long recognized that simulator fidelity has an impact upon instructor and trainee attitudes, and attitudes, in turn, have an influence upon simulator training effectiveness. Flexman[1] described this influence as follows (p. 69): "Fidelity of simulation can operate as a motivational variable. If the simulator looks, acts, feels and sounds like the airplane, then the trainee is more likely to be convinced that practice in the device will be beneficial to him." Spring[1] reported that eliminating platform motion during training in an air-to-air combat simulator was viewed by the pilots as causing a significant reduction in realism, and "there was no enthusiasm for the simulation with this limitation" (p. 4). An attempted simulator study by the Coast Guard in which performance measures were being compared under motion and no-motion conditions had to be terminated because the participating instructor pilots complained of boredom under the no-motion condition.[2]

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[1] Cited in Muckler, F. A., Nygaard, J. E., O'Kelly, L. I. and Williams, A. C., Jr. Psychological Variables in the Design of Flight Simulators for Training. Technical Report WADC 56-369 , Aerospace Medical Laboratory, Wright-Patterson AFB, OH, 1959.

In circular fashion, attitudes also influence simulator design. Williges, Roscoe and Williges[3] noted the importance of pilot acceptance on simulator design when they stated that decisions to include complex and expensive motion systems in simulators are invariably determined by pilots' attitudes. The attitudes of pilots toward the richness of visual displays has been noted earlier.

The most direct effect of trainee and instructor attitudes upon simulator training effectiveness is probably upon their willingness to engage in simulator training in the first place. That is, devices that are viewed favorably seem to be used more willingly than those that are viewed less favorably. If the addition of a motion system or visual display to a simulator will result in favorable trainee and instructor attitudes toward simulator training and, hence, greater utilization of the device, it is possible that more effective simulator training will result from the greater utilization, even though the motion and visual features per se may contribute nothing directly to transfer.

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[1] Spring, W. G. Advanced Flight Simulation in Air Combat Training. Paper presented at American Institute of Aeronautics and Astronautics Visual and Motion Simulation Conference, Dayton, OH, April 26-28, 1976.

[2] Personal communication, H. K. Povenmire, U. S. Coast Guard Aviation Training Center, 1976.

[3] Williges, B. H., Roscoe, S. N. and Williges, R. C. Synthetic Flight Training Revisited, Human Factors, 1973, 15, 543-560.

It would be a mistake to attribute all favorable attitudes toward simulator training to high fidelity. Although informal observation suggests a high correlation exists between these parameters, there are relatively low fidelity devices that are viewed favorably by many trainees and instructors, and some quite sophisticated devices have been maligned unbearably by some of the same people. One relatively low fidelity device used extensively by the U. S. Army as an instrument trainer for a number of years was extolled by the device instructors, maligned by flight instructors, and described variously as a hindrance or an aid by trainees. A study of the effectiveness of training conducted in the device was less ambiguous: the training was useless.[1]

A number of factors other than simulator fidelity that appear to be related to attitudes toward simulator training were noted during the current Air Force survey. For example, an apparent relationship was noted between expressed attitudes toward simulator training and the proportion of training received by an individual in a simulator. While no attempt was made to quantify the relationship, it was the writer's observation that attitudes toward the worth of simulator training were more positive in those situations in which the limited availability of aircraft for training forced greater reliance upon simulation. It was observed that pilots whose access to aircraft was limited to a few hours per month spoke more favorably about simulator training than did those pilots whose duties involved more frequent flying. Further, WSOs, whose CCT training included less flight time than did the pilots with whom they were paired, also spoke more highly of the simulator than did the pilots. Finally, it was noted that aircrews in training programs that involved a relatively high ratio of simulator-to-aircraft training time appeared more favorably inclined to simulator training than did those aircrews undergoing training in programs involving lower simulator-to-aircraft ratios.

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[1] Isley, R. N., Caro, P. W. and Jolley, O. B. Evaluation of Synthetic Instrument Flight Training in the Officer-Warrant Officer Rotary Wing Aviator Course. Technical Report 68-14, Human Resources Research Organization, Alexandria, VA, 1968.

Another factor involved the general intensity of simulator training activities. A tendency was noted at some Bases to try to pack as much activity as possible into the time allotted to simulator training. At one Base, there appeared to be a negative reaction to the intensity of simulator training that was reflected in the attitudes of the trainees. In that program, the trainees expressed dread of scheduled training in the device, explaining that training events (e.g., malfunctions) occurred so rapidly that unsatisfactory performance (as judged by the trainees themselves) was almost assured. Simulator training for them was a frustrating experience. Although they acknowledged probable benefits from simulator training, their expressed attitudes toward it were unfaborable. In another program at that Base using the same device but in a less intense training program, the expressed trainee attitudes were much more positive.

Another factor that appears to influence attitudes toward simulator training is the reduced "worth" of such training, when compared with similar training efforts in aircraft, with respect to certain career goals. For example, if pilots could credit simulator training time toward the hour requirements for Flight Leader status, they would tend to view simulator training more favorably. At one Base included in the current survey, the typical squadron pilot reportedly works from about 50 to 60 hours per week. Those squadron pilots who have been assigned simulator instructing duties reportedly work an additional 6 to 7 hours per week. The attitude expressed by some of these simulator instructor pilots was that they should receive some credit for the extra time spend instructing in the simulator, either toward career goals or toward meeting their own aircraft and simulator minimum training requirements. Without such credit, they felt at a disadvantage, and they expressed somewhat uncomplimentary views about simulator training.

The attitude of simulator instructors probably is quite important because of the influence most instructors have over their students' attitudes. It was found during the current survey that the instructors' perceptions of their assignment to instruct in simulators varied widely. Instructors in all four of the Commands surveyed reported great personal satisfaction with their assignments with respect to the opportunity provided for professional development, i.e., to increase their job knowledge with respect to the aircraft for which they were training students. They invariably felt that the technical knowledge gained while serving as an instructor better qualified them for their next operational assignment.

There was no consensus, however, with respect to the likely impact of an assignment as an instructor upon their career as an Air Force officer and aircrewman. Within at least one Command, such an assignment was viewed as available only to the best qualified pilots, and the assignment was reported to be actively sought for its favorable influence upon an officer's career as well as for his personal satisfaction and professional development. In another Command, the assignment was viewed less favorably career-wise, and it was reported that some of the better qualified officers seek to avoid assignment as a simulator and flight instructor because of its low status and because it is not perceived as particularly beneficial to one's career. Personnel assigned as instructors within that Command indicated that the nature of the assignment made all the instructors appear no more than average and leads to lower OERs because of the poor visibility enjoyed by incumbents. This latter comment was endorsed especially by non-pilot instructors whose instructional duties are confined almost exclusively to the simulator. The problem of visibility was stated thus by one such non-pilot aircrewman serving as a simulator instructor: "No Colonel is going to observe simulator training."

Within all Commands, differences were found in the ways simulator instructors were treated that could affect their attitudes in other ways. The practice at Carswell Air Force Base of carrying all new simulator instructors to the American Airlines Flight Academy to be briefed upon the importance of simulator training at American appeared to boost the perception of these instructors with respect to the worth of their jobs. On the other hand, the practice at another base of assigning incoming flight instructors to be simulator instructors so they can gain more knowledge of the aircraft while waiting for a position as a squadron flight instructor to become available probably contributed to the expressed perception that being a simulator instructor is something to do until an opportunity arises to become a "real" instructor.

Except to the extent that favorable attitudes increase device use, the effects of attitude upon simulator training appears not to be as important as one might think. There has been little research on this subject, however, probably because of the difficulty in controlling attitudes during experimentation. In a study reported by Muckler, Nygaard, O'Kelly, and Williams,[1] negative attitudes toward a trainer were induced in an experimental group by stressing the device's low fidelity, while positive attitudes were induced in another group by stressing the same device's training effectiveness. During transfer trials in the aircraft, both groups were found to have benefited, about equally, from the device training, thus indicating that the induced negative attitude did not affect device training effectiveness. An interesting aspect of that study was that the negative attitude group required more training in the device to reach criterion, thus suggesting an effect of attitude upon training efficiency rather than upon training effectiveness.

No transfer study was found during the current literature review that indicated that attitude per se was a factor influencing simulator training effectiveness. On the basis of the writer's experiences, it appears that just the reverse may be the case; simulator training effectiveness influences attitudes toward simulator training. Abrupt shifts in attitudes, particularly among instructors and training program managers have been observed following demonstrations of simulator training effectiveness. In one instance, instructors' very negative attitudes toward reduced scale paper mockups of a cockpit became favorable when they discovered that, unknown to them, their better students were using these "devices" on their own. In a study conducted jointly by the Airline Pilots Association, the Federal Aviation Agency, United Airlines, and the U. S. Air Force, pilots' opinions concerning simulator training were found to be more favorable following their participation in an effective simulator training program than were the opinions of non-participating pilots.[1]

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[1] Muckler, F. A., Nygaard, J. E., O'Kelly, L. I. and Williams, A. C., Jr. Psychological Variables in the Design of Flight Simulators for Training. Technical Report WADC 56-369 , Aerospace Medical Laboratory, Wright-Patterson AFB, OH, 1959.

In spite of a lack of supporting research evidence, there is a consensus among trainees, instructors and administrators that favorable attitudes toward simulator training increase training effectiveness. This probably is correct, at least in the sense that more extensive use will be made of simulators if they are viewed favorably. It may be, however, that attitudes are influenced more by simulator training effectiveness, than the other way around. A well conducted "test" of the training effectiveness of a simulator may be a very influential factor in assuring that its training value will be realized.

Expectations

Many aviators accept the proposition that training in a simulator might be helpful, while viewing it as less effective than training in an aircraft. It has been the writer's observation that simulator training administered under the control of such individuals never exceeds their expectations. If simulators are viewed as useful only as procedures trainers or as instrument trainers, they tend to be used only as procedures or instrument trainers, even though the same devices might be used more effectively by others who view them as offering a greater range of training opportunities. If simulators are viewed as useful only for the initial stages of the development of a particular skill, to be followed by further development of that skill in the aircraft, simulator training is less effective than if simulators are viewed as substitutes for the aircraft to be used for the development of a particular skill to criterion before transferring to the aircraft. While simulator training may not always prove as effective as some might expect, expectations appear to place a limit upon realized effectiveness by limiting the manner and extent of simulator training.

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[1] Meyer, D. E., Flexman, R. E., Van Gundy, E. A., Killian, D. C. and Lanahan, C. J. A Study of Simulator Capabilities in an Operational Training Program. Technical Report AMRL-TR-67-14, Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, 1967.

Expectations can influence simulator training effectiveness in more subtle ways as well. The expectation that a simulator training program will prove ineffective can influence its evaluation in the expected direction. Research by Rosenthal[1] has shown that, even with no intention to do so, an experimenter influences the outcome of his research in the direction of his expectations. Since many "tests" of the effectiveness of simulator training are conducted by pilots who hold strong views concerning the value of simulator vs. aircraft training, it must be assumed that their expectations can and sometimes do influence the test data. In those instances in which there is real or perceived pressure from a higher authority to reach a particular finding concerning the utility of a particular simulator, the effect might be even greater.

There is an almost infinite number of factors that might shape expectations concerning simulator training effectiveness. One factor is prior experience with simulator training. The initially favorable attitude toward simulator training of recent UNT graduates noted above was attributed to their favorable experiences with the simulator used during UNT, and the more favorable opinions of commercial airline pilots toward simulators was attributed to their participation in an effective simulator training program. Total flight time is probably also a factor, since more experienced pilots are more likely to have had unsatisfactory experiences with old simulators and typically put greater confidence in inflight training.

Miscellaneous Factors

There are a host of other factors that can be presumed to influence simulator training effectiveness, although it would be difficult to demonstrate conclusively that any of them is significant in a particular instance. For example, a factor that probably has had a negative influence upon the effectiveness of one or more of the Air Force simulator training activities included in the present survey is the resistance put forth by some of the personnel involved to the idea of using simulators for training rather than aircraft. Training in simulators, particularly for many of the more senior aircrews, represents a significant change from well established and well accepted training practices, and changing from one practice to another has often been resisted by the personnel involved for no reason other than that it is different.

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[1] Rosenthal, R. Unintended Communication of Interpersonal Expectations, American Behavioral Scientist, 1967, 10. 24-26.

A review of the research literature on the process of effecting change, such as substituting simulators for aircraft in aircrew training as has occurred in the Air Force in recent years, has been prepared by McClelland.[1] In that review, McClelland states that the introduction of a new training device is not in itself sufficient to assure its acceptance by the personnel expected to use it. Rather, time, money and continuous effort are required to assure its effective use.

A number of the Air Force programs surveyed reflected efforts presumably intended to overcome some of the resistance·suspected to have resulted from changing from aircraft to simulators. For example, as a means of emphasizing the value of simulator training, several of the Commands are requiring that the simulators in subordinate units be used for training at relatively high rates, such as 80 hours per week. Such a requirement may well have an eventual favorable influence upon attitudes toward changing to simulators. In the meantime, however, the requirement that a simulator be used for a specified number of hours per week increases the likelihood that at least some simulator training will be ineffective. Since such a requirement is essentially unrelated to training needs or to numbers of personnel to be trained, keeping the simulator busy sometimes involves repeating training missions or exercises that already have been mastered. Further, at one Base where such a requirement existed at the time of the survey, there were reports of instances in which the ratio of time spent in the simulator to time spent in simulator briefing and debriefing activities decreased although all such time was recorded as simulator training time. It was also reported that pilots (often of junior ranks) who were being required to use up the scheduled simulator time were sometimes already proficient at tasks which could be practiced in the devices.

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[1] McClelland, W. A. The Process of Effecting Change. Professional Paper 32-68, Human Resources Research Office, Alexandria, VA, October 1968.

A problem commonly believed by the Air Force personnel interviewed to affect simulator training effectiveness was inadequate maintenance. This problem was particularly apparent among some of the older simulators for which spare parts were difficult to obtain. Pilots using those older simulators described instances in which planned syllabus training activities could not be completed or were performed in degraded fashion because a portion of the simulator (e.g., the motion platform or an avionics component) was out of service. While it is sometimes necessary to cancel a simulator training period because of simulator failures, the more common practice is to complete the scheduled training period using a generally unsatisfactory simulator (and presumably deriving fewer training benefits) because of the punishing consequences of having to reschedule a lost training period at undesirable times, such as on weekends. The schedule of training use of most of the simulators included in the survey did not include spare time during duty hours for rescheduling lost training periods.

In situations in which an appropriate simulator is not available, it is sometimes necessary to make ineffective--or at least inefficient--use of the simulators which are available. For example, two C-5 simulators are available for Continuation Training at Travis Air Force Base, but part-task devices are not available for the separate training of the various crew members, e.g., navigator or flight engineer. One of the C-5 simulators is used for pilot and co-pilot training during the first four days of the five-day Continuation Training program, while the other simulator is used for navigator and engineer training. The full crew is trained together in a single simulator on the fifth day. While use of the full simulator for training only a portion of the flight crew cannot be viewed as optimum from the efficiency standpoint, the factor influencing this approach is the availability of the simulator and the non-availability of part-task devices. Alternative and possibly more effective solutions would be to have simulators more appropriately designed to the training requirement or to develop training programs which would permit training of entire crews in a single simulator.

Finally, the presence or absence of a simulator instructor was suggested at one Base as a likely influence upon simulator effectiveness. At that Base, some simulator missions are graded while others are not, and a qualified instructor is required to be present only during graded flights (this particular device is normally manned by both a simulator instructor and a non-rated simulator operator who has no instructional responsibilities). Several pilots undergoing Continuation Training there expressed the opinion that the absence of an instructor during certain training flights deprived them of critiques that might increase the effectiveness of the training they were receiving.

While the absence of an instructor in that particular training program may have reduced the effectiveness of the training, it is not necessarily true that an instructor must always be present for simulator training to be effective. A recent study by Tyler, McFadden, Eddowes, and Fuller[1] compared the effectiveness of simulator training in an instrument training program in UPT under experimental conditions which included tutoring by a qualified flight instructor and self-instruction in which case no instructor was present. They found that, for the training objectives under consideration, the participation of the instructor added nothing to the effectiveness of the simulator training. It is likely that there may even be positive benefits associated with removing the instructor during selected training activities in some situations, since it has been observed to lead to problem-solving behavior that may not be easily elicited when an instructor is present.[1]

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[1] Tyler, D. M., McFadden, R. W., Eddowes, E. E., and Fuller, R. R. Investigation of Diagnostic, Error Detector, and Self-Taught Instructional Strategies for Flight Simulator Programs. Technical Report AFHRL-TR-76-65, USAF Human Resources Laboratory, Williams AFB, AZ, October 1976.

COMMENT

The foregoing discussion of factors noted during the current survey of Air Force simulator training programs is, of course, largely speculative. Since there was no objective evidence concerning the effectiveness of any of the simulator training programs surveyed, there could be no direct evidence that their effectiveness was attributable to any one or more of the factors discussed herein. The effectiveness of Air Force simulator training undoubtedly is subject to many obvious, as well as subtle, influences, and it is quite likely that many of the factors involved interact in unexpected and possibly unpredictable ways.

It should be noted that the Air Force currently is engaged in a continuous program of revising its simulator training activities. Awareness of the probable influence upon simulator training effectiveness of factors such as those identified above was apparent on the part of many of the personnel involved in those programs. Deliberate efforts were noted at many Bases to improve simulator training by improving device fidelity, selecting qualified instructors, influencing attitudes and expectations, and manipulating many of the other factors that, either through consensus or evidence from the research literature, are believed to influence simulator training effectiveness. It is unfortunate that firm evidence does not exist as to how to manipulate the various influences in combination to produce the optimum simulator training program.

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[1] Caro, P. W., Isley, R. N. and Jolley, O. B. Mission Suitability Testing of an Aircraft Simulator. Technical Report 75-12, Human Resources Research Organization, Alexandria, VA, June 1975.

IV. RECOMMENDATIONS

INTRODUCTION

The project reported here was undertaken in an attempt to gain a better understanding of how simulator training might be made more effective in the Air Force. To that end, a number of factors that influence the effectiveness of such training have been identified through surveys of representative Air Force simulator training activities and through reviews of relevant research and technical literature. In some instances it is likely that merely calling attention to these factors will result in their being manipulated by personnel responsible for simulator training programs, and the effectiveness of those programs may be enhanced as a result. To the extent that this does occur, the Air Force will benefit directly from the information developed during this study.

In other instances, however, the information about simulator training may not be such that it can be used directly by personnel involved in that training. For example, use of some of the information may be precluded by administrative considerations beyond the control of those who design simulators or those who conduct simulator training. Further research may be required to determine the significance or even the accuracy of some of the information involved, or to indicate how the factors identified during the project might be manipulated to best advantage. The need for administrative action and further research on simulator training effectiveness is the subject of Section IV of this report.

RECOMMENDATIONS

The recommendations which follow are derived from the information developed during this project and presented in Sections II and III of this report. These recommendations are for both administrative action by the Air Force and for further research and development activities. The intent of each recommendation is to increase the effectiveness of present and future Air Force simulator training activities or to develop information that will lead to increased simulator training and/or cost effectiveness in the future.

The recommendations are presented below in an order that parallels the presentation of related information in Sections II and III of this report.

Thus, recommendations related to determining simulator training effectiveness are presented first, followed by those related to the various factors influencing simulator training effectiveness which are discussed in the report. This ordering was selected for the convenience of the reader who may wish to review earlier discussions related to specific recommendations.

Determining Simulator Training Effectiveness

In general, too little emphasis has been placed upon validation of simulator training programs in the Air Force. Validation efforts that have taken place have tended to be unsystematic in nature, to be made by personnel untrained in evaluation methodologies, and to rely heavily upon the subjective judgment of personnel who are untrained in the making of such judgments or who may have vested interests in the outcome of the validation studies. It is recommended that emphasis be placed at all command levels upon validating each simulator training activity, employing validation study design models that emphasize objective measurement of trainee performance against predetermined performance standards in the operational aircraft. Technical reports documenting each such study's findings and the methods employed in conducting the study should be a formal requirement of each validation effort.

It is recognized that the Air Force may not always have adequately trained personnel available to design, conduct and report simulator training effectiveness validation studies. Therefore, it is recommended that a program be initiated to identify or develop the resources necessary to accomplish these studies. Such a program should include special training for personnel responsible for simulator training program validation, the provision of consultants (either Air Force or contract personnel) to assist in the design and conduct of the studies, and the development of detailed procedural manuals to be followed in the studies' conduct and reporting.

Simulator Design--Design for Training

Air Force simulators are based upon various design concepts, most of which appear to be more closely related to reproduction of features of the aircraft than to provision of an environment optimized for training. This is not surprising, since design guidelines that relate specific simulator features to training objectives and processes often do not exist. Fundamental design problems, such as the location and functions of instructing personnel, appear to have been resolved in the design of many Air Force simulators in a manner which emphasized fidelity of simulation of the aircraft. The emphasis in the design of some Air Force simulators appears to have been only secondarily upon their training purposes.

It is recommended that a systematic program of research be initiated by the Air Force that will examine simulator design considerations as a function of specified training objectives and of the manner in which the devices are to be used to achieve those objectives. Emphasis in such research should be upon defining the roles of the instructor and other personnel involved in the instructional process (e.g., other aircrew members) and upon identifying training processes that could be employed to enhance simulator training effectiveness and efficiency. Design concepts should be sought that will emphasize the simulators' training purposes rather than the characteristics of the aircraft being simulated. Such research should incorporate efforts in which existing Air Force simulators are examined to determine the limitations their various designs place upon the manner of their use as well as efforts to develop and test alternative simulator design concepts for various training requirements. This research should attend to all simulator design features which can impact training effectiveness. Examples of such features include overall simulator configuration and manning requirements as well as the provision of instructional aids such as record-playback and automatic adaptation of program difficulty to trainee error rates.

Simulator Design--Visual Fidelity

Simulator design is undergoing a major change with respect to visual simulation. Whereas only one of the simulators examined during the present survey incorporated an extra-cockpit visual display, many future Air Force aircraft simulators will have such displays or will be designed so that such displays can be added. Presumably, the costs to the Air Force of these additions to future simulators are justified because of the increased training value they will provide. It should be noted, however, that this presumption is neither supported nor refuted by presently available research findings. Instead, the presumption is supported by a desire to increase the physical correspondence between the simulator and the aircraft training environment in the area of visual cues, and thus to increase the apparent scope of training for which the device is suitable.

Present day visual display technologies are limited, and display costs are high. Therefore, the need for visual displays should be examined, and the training effectiveness of existing simulators without visual displays for skills involving extra-cockpit visual cues should be investigated. The extent to which presently existing Air Force simulators without visual displays can be used to meet visual training objectives--or at least to reduce the time required in the aircraft to meet those objectives--has not been established. There are probably a number of visual training objectives which are dependent upon extra-cockpit visual simulation, but it is also possible that many that presently are presumed to be so dependent, in fact, are not.

Research to find alternatives to expensive extra-cockpit displays, such as displays inside the simulator cockpit and cognitive pre-training conducted in the classroom, also would appear to offer possible visual training benefits at relatively modest costs. For many visual training needs, an extra-cockpit display simply may not be necessary. For others, of course, it may be essential.

It is recommended that a program of visual simulation research be undertaken in which attention is directed to the cognitive and visual cues essential to the attainment of the visual training objectives associated with various aircraft systems and missions. Emphasis in such research should be upon analytic efforts directed to the tasks to be trained and upon the development of simple models and/or analogs of visual scenes consisting of essential cues which can be displayed inexpensively to the simulator pilot. The goal should not be simply to reproduce a particular visual scene, or even to produce a "low fidelity" representation of that scene, but to determine the cognitive and visual cues essential to the elicitation of training objectives.

Present visual display research, directed primarily to the development of techniques of image generation, storage, and display, should not be affected by the conduct of the research recommended above.

Simulator Design--Motion Fidelity

The recent reports that performance in the aircraft may not benefit from the presence of cockpit motion were welcomed by many who have been concerned about the costs of procuring, maintaining, and housing modern platform motion systems. In some instances, the limited scope of these recent motion studies may have been overlooked because of the potential savings their results would permit. Since these studies' results are not completely consistent with the results of other simulator motion research, however, the inconsistencies should be examined carefully.

The distinction between maneuver and disturbance motion provides a convenient conceptual framework within which to examine the apparent difference between findings of the earlier research on motion and the Jacobs and Roscoe and the ASPT studies' findings that motion may not be important in training. It is clear that in the studies in which motion did not appear to influence pilot performance, the motion involved was predominantly, if not exclusively, of the maneuver variety. On the other hand, disturbance motion was the predominant type of motion in studies in which a contrary finding was suggested. Thus, it appears that the results of both sets of studies can be accepted and attributed to the limited nature of the motion simulation involved in each. Disturbance motion is important, at least in training situations where disturbance cues are important and when the aircraft simulated is unstable or particularly responsive to control input. Maneuver motion may be important also under some of these circumstances, but the evidence available at this time has not shown that it contributes to transfer of training.

Because the distinction between maneuver and disturbance motion has only recently been articulated, there has been little opportunity to examine systematically the influence of each upon simulator training effectiveness. Most prior training research on motion appears to have dealt primarily with maneuver motion, and maneuver motion appears reasonably well represented in the newer simulators, although time lags between pilot manipulation of aircraft controls and motion system responses have been a major problem in some of them. Disturbance motion has been less thoroughly investigated, and is poorly represented in some newer simulators.

Additional research upon the role of disturbance motion in training is clearly needed, and a program of such research is recommended. Emphasis in the research should be three-fold: (1) analysis of disturbance motion cues associated with specific simulator training objectives; (2) development of models for the representation of critical components of such motion in simulators (e.g., rates of onset, direction of movement, and duration); and (3) determination of the effects upon transfer of training of the presence and absence of such motion. Because of the continuing concern over the costs associated with motion simulation, future research on motion simulation should also examine the use of motion systems with limited axes of motion, g-suits and seats, and "seat shakers" to determine whether the disturbance cues found to be important in training can be represented adequately in such relatively low cost motion devices. In any event, future motion system designs should be responsive to requirements to provide specific movements which cue specific pilot responses rather than to provide motions which simply correspond to motions of the simulated aircraft.

Simulator Design--Handling Characteristics

Aircraft response and handling characteristics received significant research attention several decades ago when then-available analog simulation techniques made faithful simulation of an aircraft both difficult and expensive. Present day technologies are such that close approximations to almost any aircraft flight characteristic can be achieved in a simulator at relatively modest costs. Therefore emphasis has shifted from research to establish the necessary minimum levels of fidelity of handling characteristics required to assure simulator training effectiveness, to the development of digital computer modeling and programming techniques which improve such fidelity. Major investment of training research resources in simulator handling characteristics research does not appear warranted at this time.

Training Programs

While it is generally acknowledged that the manner in which a simulator is used limits its training effectiveness, relatively little attention has been devoted to the development of optimum ways of using these devices. Except to the extent that general learning concepts may be applied to the simulator training situation, few research-based guidelines exist for the simulator training program developer to follow in establishing his training program. An obvious recommendation from the present study is that more effort be devoted to research on how to manipulate variables believed to affect learning in a simulator training situation.

It did not appear to the writer that the effectiveness of a majority of the simulator training programs included in the present survey was constrained by a lack of research, however. Instead, instances were noted in which practices did not make full use of available information about human learning and performance. Training programs in which knowledge of results and reinforcement were withheld until training was completed, for example, would not appear to be designed around current understandings of learning processes. It is believed that a thorough review of each Air Force simulator training program by personnel whose expertise lies in the area of human learning and performance would provide numerous suggestions for program development and modification to be considered by those whose areas of expertise lie in operational flying and flight training. Such reviews are recommended.

The Air Force currently is redefining its simulator training activities through the application of the Instructional System Development (ISD) process. It is expected that these ISD efforts will have a significant impact upon simulator training, particularly with respect to the content of simulator training. It is recommended that these efforts be encouraged and expedited where possible in both combat crew training and continuation training programs.

Personnel - Trainees

The Air Force and other training agencies have invested heavily in research to develop an effective means of selecting aircrew trainees. Numerous variables which predict the effectiveness of flight training have been identified, and many of these same variables probably predict simulator training effectiveness equally well. Since personnel selected for aircrew training have all been screened to eliminate those for whom initial flight and simulator training programs could be predicted to be ineffective, it should not be expected that factors would be found that would affect undergraduate level simulator training effectiveness differentially for different groups of selectees. The selection process has assured that aircrew trainees are homogeneous with respect to those factors that might be influential in that regard.

On the other hand, it might be expected that simulator training effectiveness--and flight training effectiveness--might well be related to flight experiences gained by aircrews subsequent to completion of the selection process, since these experiences are known to vary widely. The findings of the present survey and literature search do not support that expectation. Instead, it was found that simulator training can be effective for the neophyte as well as for the highly experienced pilot. However, these findings do suggest that simulators should be used differently for aircrews with different levels of experience if simulator training is to be equally effective for all. Therefore, it is recommended that more emphasis be placed upon identifying the needs of the individual trainee in Air Force simulator training programs than was typically noted during the present survey. Rather than having standard simulator training syllabi for each aircrew position which all assigned personnel must complete, simulator training would be more effective if individual skill deficiencies were diagnosed, and simulator training content and duration were tailored to those individual needs. A training system that does not recognize differences among trainees is an inefficient system at best. Its chief virtue lies in the relative ease with which it may be administered.

Personnel - Instructors

The role of the instructor in Air Force simulator training programs has not been well defined. Most often in the programs surveyed, the instructor was viewed as an expert aircrewman who, because of his competence in the cockpit of an aircraft, knows what to do and how to do it in order to train students in a simulator. Just what it is that he does that makes him a good simulator instructor was not clear, however. While there was unanimous agreement that some simulator instructors are better than others, there were differences in the way good instructors were characterized.

It is recommended that attention be devoted to the specification of criteria for the simulator instructor, i.e., what does a good instructor do that distinguishes him and his students from other instructors and their students? It is believed that the inattention to simulator instructor training noted during the current survey results from the fact that most of the personnel interviewed were not sure what the content of such training should be. If training effectiveness and efficiency are related to the skills and techniques of the simulator instructor, then it is important that personnel selected for such assignments be provided the training that will permit them to develop such skills and techniques. Before such training can be provided, those skills and techniques must be identified. It is also recommended that simulator instructor training programs be developed to provide the needed training as soon as the requirements of that training can be identified and validated.

Attitudes, Expectations and Miscellaneous Factors

It has been the writer's experience that few aircrewmen can be persuaded that simulator training is effective. Instead, they must be shown. A well designed, conducted and documented test or study that demonstrates that a particular simulator training program is effective can have favorable influences upon trainee attitudes and expectations toward such training. The recommendation made earlier in this report that validation studies be conducted of all Air Force simulator training activities is underscored here, because such studies can provide the effectiveness demonstrations needed to increase willing participation in simulator training. These demonstration studies are of particular importance in instances in which a simulator may lack a dimension of fidelity, e.g., platform motion, that is viewed as important by the trainees who must use the device.

It is also recommended that personnel responsible for the oversight of simulator training in the Air Force examine some of the administrative practices associated with that training. Questions should be raised on both a command and a local level as to whether any such practices are likely to affect simulator training attitudes and expectations in negative ways. A number of suspect practices were noted during the present survey: training schedules that are unduly lengthy or interfere unnecessarily with off-duty activities; failure to give an aircrewman credit toward career goals for simulator training accomplishments when such credit is readily available for comparable performance in aircraft; and awarding a lower status to simulator instructor assignment than to "real" or in-flight instructor assignment. Systematic examination of such administrative practices and restrictions could lead to more favorable attitudes toward simulator training.

An examination of administrative practices may also identify factors that might influence simulator training effectiveness more directly. Practices that emphasize training processes such as syllabus completion and high levels of personnel activity instead of training objectives do not necessarily lead to highly effective training. Objective examination of the needs for such practices might lead to the identification of alternatives which would be more beneficial.

COMMENT

Our understanding of factors influencing the effectiveness of simulator training is quite limited. While there are many opinions on the subject--almost everyone involved in activities related to simulator training is something of an expert--there was little agreement among the Air Force personnel interviewed during the project as to how simulators should be designed and used for training. The literature reviewed was equally inconclusive in most instances. There has been very little reported research on training simulator design and use, and that which has been reported often identifies more issues than it resolves. An obvious conclusion to be drawn from the present study is that too little attention has been paid to date to the effectiveness of simulator training.

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APPENDIX

ON-SITE SURVEY OUTLINES

A. Simulator Design (Directed to simulator operators and instructors and conducted in conjunction with an inspection of the simulator.)

1. Describe motion
2. Describe visual
3. Describe IOS
    a. location
    b. principal training features
    c. adequacy for intended purpose
    d. needs for redesign
4. Describe trainee positions
5. Pilot comments
    a. handling characteristics
    b. motion
    c. visual
    d. adequacy of malfunction simulation
    e. adequacy of environmental simulation
    f. needs for redesign
    g. miscellaneous
6. Suggested modifications

B. Simulator Training Effectiveness (Directed toward personnel responsible for administration and management of simulator training.)

1. Demonstrated effectiveness
    a. report identification
    b. design model
    c. describe data and results
    d. factors influencing results

2. Assumed effectiveness
    a. describe perceptions
    b. basis
    c. documentation
    d. factors influencing perception
3. Command attitudes/perceptions
4. User attitudes/perceptions
5. Factors influencing effectiveness

C. Trainees (Directed toward personnel undergoing CCT and CT at the time of the interview.)

1. Source of trainee input
2. Typical prior operational experience of trainees
    a. hours logged by A/C types
    b. aircraft flown
    c. type of unit
3. Prior experience with simulators
    a. prior devices
    b. recency of device design
    c. completeness of device design
    d. expressed attitudes
4. Expressed attitudes/expectations concerning present simulator training
5. Suggestions for change
    a. simulator design
    b. simulator use
        (1) program content, sequence, etc.
        (2) simulator training schedule
    c. other

6. Perception of simulator training
   - a. overall value
   - b. specific benefits/problems

D. Instructors (Directed toward personnel serving as simulator instructors at the time of the interview.)

1. Instructor type and personal data
2. Selection prerequisite
3. Describe simulator instructor training
4. Other duties and time requirements
   - a. flight instructor
   - b. classroom instructor
   - c. administrative
   - d. miscellaneous
5. Typical prior operational experience
   - a. hours logged in aircraft simulated
   - b. total flight time
   - c. types of units
6. Typical prior instructor experience
   - a. simulator
   - b. other
7. Perception of their assignment
   - a. effects upon career advancement
   - b. value of experience being gained
   - c. personal satisfaction
8. Factors perceived to influence instructor effectiveness